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DEPARTMENT OF COMMERCE

UNITED STATES BUREAU OF MINES
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MAGNESITE

BY

PAUL M. TYLER

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MAGNESITE[1]

By Paul M. Tyler[2]

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INTRODUCTION

Magnesite is of importance primarily as a refractory material for lining steel furnaces, although substantial amounts are used in the production of flooring compositions and other building materials and for certain chemicals, notably epsom salts. Since consumption for all of these purposes is largely in the eastern United States and domestic deposits are situated in California and Washington, this country's magnesite mining industry, which was created largely by war-time conditions, has subsequently been sustained by tariff protection.

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1 The Bureau of Mines will welcome reprinting of this article, provided the following footnote acknowledgment is used: "Reprinted from U. S. Bureau of Mines Information Circular 6437."

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The cost of transport of the domestic product from coast to coast and the duties on imported magnesite have stimulated the search for substitutes, and as a result the consumption in recent years has been somewhat less than it was in 1913, for example, when supplies from Austria-Hungary and Greece were freely available. Magnesite is still an essential material for the steel industry, but the quantity used per ton of steel made, never very great, has been much reduced due to a larger use of dolomite and chromite as refractory materials.

Before the war between 6 and 14 pounds of magensite were consumed to make a ton of steel, but economics enforced by the abrupt stoppage of imports from Austria-Hungary in 1914 soon reduced the consumption by one-half. The tendency to restrict the use of magnesite is still apparent. In 1929, the domestic output of steel ingots and castings amounted to 56,433,473 (long) tons as compared with only 30,966,000 tons in 1913, but the indicated supply of magnesite, dead-burned for refractory purposes, was only 125,082 (short) tons as compared with approximately 164,000 tons available in 1913. Since it is reasonable to assume that the consumption of dead-burned magnesite in the production of nonferrous metals and for miscellaneous purposes has not declined, these figures alone tend to indicate the magnitude of the market that has been lost by magnesite producers and importers. The steel industry, on the other hand, has made its position more secure. Formerly dependent solely upon Central Europe for this important material it now obtains about two-thirds of its magnesite from domestic mines and in addition uses other refractory materials both foreign and domestic, the supply of which can not be so quickly cut off by national or even international disturbances.

DESCRIPTION AND USES

Crude magnesite is the natural carbonate of magnesium. When pure it contains 47.6 per cent MgO and 52.4 per cent CO_2, but frequently iron and manganese replace part of the magnesium. An iron-bearing variety (5 per cent or more FeO) is known as "breunnerite." Mesitite, 2 $MgCO_3.FeCO_3$, and pistomesite, $MgCO_3.FeCO_3$, are subspecies of minerals intermediate between ferruginous magnesite (breunnerite) and iron carbonate (siderite). According to Dana the ordinary magnesite may be (a) crystallized (rare); (b) lamellar (cleavable); (c) compact (fine granular); (d) compact (like unglazed porcelain in fracture); or (e) earthy. The earthy material may be mixed with hydrated silicate of magnesia or sepiolite (meerschaum). Baudisserite from Baudissero, near Turin, which has some resemblance to chalk and adheres to the tongue, is an earthy type of magnesite. Even the purer varieties of compact magnesite usually contain more or less of the silicate. Dolomite or magnesium limestone is frequently found in magnesite deposits and is a source of lime, an undesirable impurity. Some lime, however, apparently is present in certain kinds of magnesite in molecular combination.

The two principal forms of magnesite are amorphous and crystalline. Amorphous magnesite, the more common of the two, is a fine-grained compact mineral, usually white or cream colored and having a more or less conchoidal or porcelain-like fracture. It usually occurs as veins or masses in serpentine.

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Crystalline magnesite resembles marble in appearance and it occurs as masses, usually replacements, in metamorphosed limestone, dolomite, or associated sediments. While resembling limestone or calcite in appearance magnesite is harder (H., 3.5 to 4.5) and much heavier (sp. gr. 3 to 3.12). It dissolves in acids somewhat less readily even than dolomite, and unlike calcite does not effervesce in cold dilute hydrochloric acid.

Dead-burned magnesite is obtained by calcining crude magnesite at a high temperature so as to drive off practically all the carbon dioxide. Ordinarily the grades of magnesite chosen for this purpose contain a small percentage of iron which sinters with the magnesium oxide and forms lumps or so-called "grain" magnesite varying in size of particles from sand up to kernels about 1 inch in diameter. The presence of iron also tends to lower the temperature necessary for effective removal of the carbon dioxide and the iron oxide is said to act as a catalyzer, favoring the formation of an inert (beta) variety of magnesium oxide. Dead-burned magnesite is employed as refractory; about one-half of the domestic consumption is used in the form of brick and special shapes, and one-half is purchased in loose condition by the furnace companies.

Caustic calcined magnesite is calcined at a considerably lower temperature in order to retain about 3 per cent CO_2 in the product. In this form the residual magnesia combines readily with water and carbon dioxide in the air (compare quicklime) and with various acids for the manufacture of salts. This form of magnesia which is relatively soluble or active has been called "alpha" magnesia. The principal use of caustic calcined magnesite is in magnesium oxychloride (Sorel) cement for floorings, stucco, and wall plaster. Other uses include employment in the manufacture of Epsom salts, as a chemical accelerator in rubber, as heat insulation, and as material for small moulded articles such as tobacco pipe bowls. In the chemical industry magnesite may displace lime as a neutralizing agent and precipitant of stearin, glycerol, and soap. In the explosives industry it is said to have been used instead of diatomite as a filler for dynamite. It has been employed as a filler in automobile tires, and certain varieties of vitreous porcelain are made from magnesite. Since Sorel cement adheres firmly to wood, its use has been suggested for protecting railroad ties. Magnesite "lumber" made from wood shavings (or excelsior) held together by oxychloride cement is one of the newer outlets. Magnesite wall board has become a fairly important item, and lath, tacking strips, shingles, and baseboards are used to an increasing extent in modern fireproof buildings. Formerly calcined magnesite was used in making magnesium bisulphite for paper making. It has also been used in boiler compounds for neutralizing acid water.

According to a study made by the United States Tariff Commission, the domestic consumption of caustic magnesite during the first nine months of 1923 was distributed as follows:

Use	Percentage of total
Stucco	73.6
Flooring	12.8
Rubber trade	1.2
Insulation	1.5
Chemicals	6.9
Not determined	4.0
	100.0

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Later figures are not available but the prevailing impression is that the consumption in stucco after increasing for a year or two has subsequently fallen off greatly and that the quantity used in flooring has increased, at least relative to the consumption in other products. The manufacture of magnesite lumber and fireproofing insulation (e.g. Thermax) is a new factor in demand and had not made an appearance in the United States in 1923.

For many years crude magnesite was used for the manufacture of carbon dioxide gas, the residue being employed by the sulphite pulp mills in Californi. In recent years, however, most magnesite is calcined at the mines, the potentia value of the gas being more than offset by the saving in freight. In 1929 no crude magnesite was sold by domestic miners and only 300 tons of magnesite were imported without being calcined. Chemical manufacturers and others that formerly bought crude magnesite find it cheaper to use the caustic calcined materia Crude magnesite, finely ground, has been used as a constituent of paints, but magnesium silicate or talc is the magnesium material used most commonly as a pigment.

Formerly great importance was attached to the physical nature of crude magnesite. Amorphous (or cryptocrystalline) material was considered suitable only for making caustic calcined magnesite, and crystalline magnesite was used exclusively for dead-burned magnesite. In later years, however, it has been found possible to employ crystalline magnesite, mined in Washington, for magnesite cements, and the California amorphous magnesite is now being made successfully into high-grade refractories.

Typical Analyses of Dead-Burned and Caustic Magnesite

Origin	MgO	CaO	Fe_2O_3-Al_2O_3	SiO_2	Ignition loss
American (Washington) grain[1] ...	83.04	3.11	7.02	6.78	- -
Do. ...	84.00	2.30	7.38	6.40	0.50
Austrian grain[1]	84.97	3.10	[2]8.64	2.91	0.32
Do.	86.50	2.75	7.50	2.50	0.50
Australian (B.H.P.) grain	83.22	3.27	5.06	5.09	3.55
Caustic, Commercial:					
Average[3]	83.1	3.61	0.8	6.1	[4]6.2
Maximum[3]	92.00	16.50	4.60	13.68	16.00
Minimum[3]	66.06	0.34	0.05	1.80	1.10

1 U. S. Tariff Commission. Information Survey FL-24, 1922, pp. 44-45.
2 Includes 0.68 per cent Mn_3O_4.
3 Analyses of 40 samples, both foreign and domestic, made in laboratories of Dow Chemical Co. (Midland, Mich.) in 1925.
4 Includes 2.7 per cent CO_2.

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SUBSTITUTES

For many purposes dolomite, or high-magnesium limestone, is an active competitor of magnesite. In the manufacture of carbon dioxide and in the sulphite process of paper manufacture, - the main outlets for domestic magnesite previous to 1914, - magnesite has been largely displaced by cheaper dolomite or limestone and in the East dolomite is used as raw material for the production of precipitated magnesium carbonate, used in pipe coverings. Other sources of magnesium are natural salts, the bitterns left after extracting common salt from sea water, and brine wells. In the refractory field, magnesite meets active competition not only from dead-burned dolomite, but also from other highly refractory products. Chrome refractories, in particular, have found a much wider use, due in part to the higher prices for magnesite in the United States since it became dutiable under the tariff act of 1922.

Magnesite bricks are quoted at $65 a short ton, which compares with $45 a ton for chrome brick. The standard size ($2\frac{1}{2}$ by $4\frac{1}{2}$ by 9 inches) weighs 9.5 pounds each in the case of magnesite brick and 10.5 in the case of chrome brick. Chrome brick, therefore, cost approximately $235 per 1,000, as compared with $310 per 1,000 for magnesite brick. In a 9-inch wall, this means a saving of almost $1 per square foot. To help meet this competition, unburned magnesite brick (using a chemical binder) has been placed on the market; they are quoted at $50 a ton, and being lighter they actually cost about the same as chrome brick. Such brick is used for the bottom layer and in the end walls of open-hearth furnaces. The use of chrome refractories has recently increased very largely. Five or six years ago the output of chrome brick was scarcely 10 per cent of the output of the magnesite brick, but at present it is estimated that the number of chrome brick produced in the United States at least equals, and may considerably exceed, the output of magnesite brick. Despite these heavy inroads into their field of use, the demand for magnesite refractories has continued to grow, due to the increased employment of high-duty refractories in place of ordinary fire brick.

Dolomite is much cheaper and far more widely distributed than magnesite. Though not so refractory as magnesite it finds a considerable application about steel furnaces. The first successful bottoms used in basic open-hearth furnaces were made of burned dolomite, rammed in with tar. Later it was found that bottoms made from dead-burned magnesite gave better service, but by employing high-lime slags and making other slight modifications in furnace operation, good steel can be made economically without the use of magnesite. Raw dolomite is almost universally used, to the extent of 40 to 70 pounds per ton of steel, as patching material. Patented products consisting of dolomite treated with furnace dust or other binder and calcined - "kendymag," "syndolag," "magnibrent," etc. - have come into use at steel plants as partial substitutes for magnesite.

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Refractories of the mullite type have made an appearance but are still too expensive to compete with magnesite. Some of the highly aluminous refractories, however, may be considered as competitive with magnesite for certain uses.

The market for caustic calcined magnesite is likewise competitive. Magnesite flooring has certain well-recognized advantages - notably its ability to withstand vibration and bending stresses without cracking - but for outside stucco white Portland cement has taken the place of magnesite materials in a great many cases. The Portland cement is not cheaper and three coats are usually required instead of two, but it takes color better and is more nearly waterproof. In cold climates, however, magnesite cements have some advantages because they will not freeze and because they set quickly. Magnesite wall board and other forms of magnesite "lumber" must compete with a highly developed line of gypsum products. At present the mainstay of the caustic calcined magnesite business is the flooring trade. Magnesite flooring, however, is expensive, costing perhaps as much as 30 cents a square foot as laid down in place in a large New York office building. Other floorings, including rubber and asphalt base patent floorings, cost 20 cents or less a square foot and under many circumstances are considered practically as desirable. Since the proper installation of magnesite flooring demands expensive equipment as well as considerable experience, the tendency is for this trade to become progressively concentrated into fewer and stronger hands. This condition in turn has tended to perfect methods for laying these floors and to stabilize the business generally. Magnesite terrazzo has been recently developed, which can be placed over old wooden floors in the form of a veneer only 5/8 to 3/4 inch thick. Patented brass strips are now inserted in magnesite floors, simulating the appearance of travertine. Such new developments tend to strengthen the competitive status of magnesite as a flooring material, especially wherever vibration and bending stresses would tend to crack other kinds of flooring or where nonslipping surface is required.

HISTORY

As noted by Mellor[3], natural magnesium carbonate was first discovered at Hrubschütz (Moravia) and named Kohlensaurer Talkerde by W. A. Lampadius in 1800; and Reine Talkerde, or Talcum Carbonatum, by C. F. Ludwig in 1803. Previously, in 1795, J. C. Delametherie had applied the term "magnesite" to a series of magnesium salts (carbonate, sulphate, nitrate, and chloride) and A. Brongniart had applied the same term to a group of minerals including the carbonate and also certain silicates. The term "magnesite" was first restricted to the natural carbonate by D. L. G. Karsten in 1808 and was gradually accepted by German mineralogists, although in France the silicates were called "magnesite" for some time, the carbonate was known as giobertite, and the silicious earthy variety from Baudissero near Turin which was analyzed by G. A. Giobert was called baudisserite.

3 Mellor, J. W., A Comprehensive Treatise on Inorganic and Theoretical Chemistry: Vol. 4, London, 1923, p. 349.

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In 1867, Sorel pointed out that a cement could be produced by mixing magnesium chloride with magnesia much in the same way as in making of the white stopping used in dentistry from zinc chloride and zinc oxide. Early attempts to make practical use of this material failed because of deferred hydration which caused it to swell and blow. According to Day,[4] Dr. Grundmann of Hirschberg succeeded in the eighties in producing a satisfactory cement by means of curing in an atmosphere of carbon dioxide. He also introduced marble dust and other inert materials into the mix. The use of magnesite cement, however, was little known until about 1913 when several thousand feet were laid in the Panama-Pacific Exposition buildings in San Francisco. During the war magnesite flooring was used on battleships, and the emplacements for Big Bertha, the gun that shelled Paris, were said to have been made of quicksetting magnesia cement. Magnesite flooring was also introduced into Pullman cars and began to be used more extensively in hospitals, restaurants, and public buildings. The use of magnesite stucco did not reach large proportions until after 1920 and by 1927 had dropped off again, at least in the United States, to relatively small proportions.

The refractory nature of magnesium oxide was recognized quite early but prior to the discovery of extensive deposits of magnesite in Styria about 1884, little or no commercial application seems to have been made of this knowledge. In 1891, 100 tons of California magnesite was used by the Pacific Rolling Mills for lining furnace bottoms but in Pittsburg and other domestic steel centers dolomite was still being used in making basic steel.[5] In fact it was not until about the beginning of the twentieth century that magnesite refractories began to be used extensively in the steel industry. The rapid increase in the production of basic open-hearth steel resulted in a fast-growing use of magnesite, but previous to 1914 the domestic supply, and in fact the supply of the world, was obtained principally from Austria and to a minor extent from Greece.

GEOLOGICAL OCCURRENCE

According to Bain,[6] magnesite deposits of commercial extent can be divided into four types: (1) Magnesite as sedimentary rock, (2) magnesite as an alteration of serpentine, (3) magnesite as a vein filling, and (4) magnesite as a replacement of limestone. Of these only the second and fourth are of economic importance at present.

The sedimentary deposits he attributes to precipitation of $MgCO_3$ in salt lakes by chemical action aided by evaporation. The vein deposits, in his opinion constitute a variety of the ordinary fissure-vein deposits of magmatic origin, and magmatic origin is likewise ascribed to the carbonated waters that produce magnesite by alteration of serpentine, although transportation and selective precipitation are essential factors in the formation of a workable deposit of serpentine. The fourth type is the most important and most complex, but the chemistry of the process is described by Bain as follows:

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4 Day, William C., Structural Materials: Mineral Resources of the United States 1888, U. S. Geol. Survey, p. 554.

5 Cf. Mineral Resources of the United States, 1891, U. S. Geol. Survey, p. 585.

6 Bain, G. W., Types of Magnesite Deposits and Their Origin: Econ. Geol., vol. 19, 1924, pp. 412-433.

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Deposits of the replacement type in at least two cases (Styria and Quebec) are normal limestones replaced by magnesia-bearing solutions emanating from a granite magma * * *.

The solutions were in the form of silicates when they reached the limestones. The solutes at a certain stage precipitated out as serpentine and talc rather than as anhydrous minerals as is usually believed to be the case. Almost simultaneously any anhydrous minerals already formed became hydrated.

Reaction between the limestones and dolomites and the silicate-bearing solutions formed magnesite or dolomite, depending upon whether the rock traversed by the solutions was a dolomite or a limestone.

The wollastonite formed during the reaction was carried away in solution as in the case of the silica in the formation of the magnesite veins in the better known deposits in serpentine.

The magnesite deposits in serpentine on the island of Euboea are considered by several writers[7] to have been derived from the serpentine by the action of descending carbonated waters, but this view is not held by Thoenen.[8]

MINING METHODS

The mining of magnesite, like that of other minerals, is governed by local conditions. In California where the deposits occur in irregular veins, lenses, masses, or stock work, large-scale operations are not possible. Glory holes may be dug where the masses are very thick, but overhand stoping with back filling is the usual method of operations after mining proceeds beyond the limits of shallow open cuts. In Washington where the magnesite occurs as massive beds, regular quarrying methods are employed in getting out the ore. Tunnels are run into the hill at convenient points and raises are put up to the quarry floor. The ore drops through such raises into small cars, which are trammed by hand to the portals of the tunnels. Practically the entire domestic output of magnesite is won by underground methods.

In eastern Canada, Quebec possesses the only known workable deposits of magnesite. Quarrying is done by open-cast methods, the rock being broken down by blasting and sledging to "one-man size." The quarried material is cobbed to separate it from excessive amounts of serpentine and highly dolomitic rock. Owing to the unavoidable lime contents, Canadian material is less satisfactory than Austrian or Washington magnesite.

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7 Sagui, C. L., The Magnesite Deposits of Euboea, Greece: Econ. Geol., vol. 24, 1929, pp. 654-657.

8 Thoenen, J. R., Notes on the Genesis of Grecian Magnesite: Am. Inst. Min. and Met. Eng., Tech. Pub. 67, Class H, Nonmetallic Minerals, No. 3, February, 1928, 9 pp.

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In Austria the deposit at Veitsch is one of the largest and the methods of mining and preparing magnesite there are typical of those employed at other deposits in the former Empire. The magnesite, which occurs in the form of a lens, is quarried on the slope of a hill in a series of terraces about 50 feet apart. The entire work extends through a vertical distance of 500 feet. The huge magnesite lens is nearly three-quarters of a mile long, over 1,000 feet in width, and extends to a considerable depth. The material is blasted out of the solid by the ordinary methods of rock quarrying. It is next broken in pieces which can be handled readily by one man and the dolomite and quartz are picked out. Even in the best sections of the deposits there is a large quantity of gangue material, and estimates of the waste rock vary from one-half to two-thirds of all the material quarried. The coarse material is cobbed to free it as far as possible from impurities (including schist, dolomite, and quartz) and the lumps are sorted. The cleaner portions of the magnesite are reduced to pieces about the size of a man's head. Less pure portions have to be broken into pieces about fist size. These dressing operations involve a considerable loss of magnesite in the form of fragments too small to be burned in shaft kilns. The raw material thus obtained in the quarries at Veitsch is transported by gravity planes to the sintering kilns at the foot of the hill.[9]

Ordinarily magnesite does not occur in pure masses and hence it is nearly always necessary to sort the material carefully at mine or quarry. Details of practice at the largest California property are described as follows by Palmer:[10]

Method of Opening a Deposit

> In opening a deposit, a main entry is driven in the footwall parallel to the vein. These entries are 7 by 7 ft. in cross section and require little timbering, as the unaltered serpentine is not materially affected by atmospheric agencies. At intervals of 150 to 200 ft. main raises are driven, with a cross section of 5 by 7 ft. to the next level. These raises are carried in the footwall until they meet the vein, and this is then followed upward. Between the main raises, at intervals of 30 ft., secondary raises are carried up approximately 15 ft., at which level they have penetrated a few feet into the vein. They are then turned each way at angles of 45° and carried in the vein on this slope until they meet.
>
> Stoping is then done by drilling holes in the back, and blasting down and drawing off only such ore as necessary to give working room. Occasional pillars are left to support the walls,

9 Phalen, W. C.: Mineral Investigations of Bureau of Mines.
10 Palmer, Leroy C., Magnesite Mining in California: Trans. Am. Inst. Min. and Met. Eng., vol. 75, 1927, pp. 747-749.

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but, with this exception the method is typical shrinkage stoping, and need not be described. Operations cease with a back from 6 to 8 ft. thick between the stope and the next level. This ore and the stope pillars will be removed when the time comes to abandon that part of the mine. Stoping is carried on by working upward from the main levels, driving a level in the vein to the end of the ore shoot and working backward until the ore is removed.***

No mechanical treatment of magnesite ore for improving its grade is practiced at the California mines, and consequently the impurities allowed in mining are restricted to narrow limits. Hand sorting is the only method of bettering, and consequently it is essential to break the ore in the stopes as cleanly as possible, and with no more admixture of wall rock than can be avoided. Furthermore, as has been noted, there is frequently a 'gouge' along the hanging wall, which latter has been more or less shattered by the processes incident to the forming of the veins. This gouge acts much as a heavy layer of cement, and helps to keep the wall in place so that it is desirable to leave it undisturbed. This also calls for careful mining. For these reasons the tonnage mined per man does not approach that usually attained in shrinkage stoping in metallic minerals, which is generally carried on in low-grade deposits where a large tonnage is sought with the expectation that any lack of care in mining will be remedied in the mill. At the Diamond the gross output per man is from 3 to 5 tons, but when waste is sorted out and fines screened only 1 to 2 tons reach the kilns.

Main drifts, which have a cross section of 7 by 7 ft., are driven with two miners and two muckers per shift. The men are paid $5.50 per shift, with a bonus of $1 per foot for every foot more than five broken per day. A standard center-cut round of from 12 to 15 holes is used, with about 50 lb. of powder per round. From 5 to 6 ft. per round is the usual progress. These drifts cost about $6 a foot.

The raises are 5 by 7 ft. in cross section, and cost $4 a foot. Stoping is done by contract. The company furnishes the machines and air, sharpens the steel, and trams the ore; the contractor furnishes labor and powder only.

The ore is loaded through hand-operated sector gates to 2-ton side-dump cars hauled by a gasoline locomotive with a Ford automobile engine. The various parts of the locomotive were hauled up the steep road to the mine and assembled there.

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Ventilation

The loading chutes are only a few hundred feet from the mouth of the haulage-way, and ventilation conditions are such that there is always a strong outcast from the haulage level, so that the gasoline locomotive can be used with safety. Haulage is through a level driven for that purpose at an elevation of 175 ft. less than the lowest operating level.

At the mine bins the ore is dumped over a $1\frac{1}{4}$-in. grizzly, the undersize from which passes to a $\frac{3}{4}$-in. screen. This gives three products, lump for the stack kilns, fine ore for the rotary kiln and dust. The latter is wasted, as it is found to run high in impurities.

CALCINING METHODS

In the United States calcination has been effected in different types of kilns: (1) Bottle-shaped kilns; (2) vertical kilns resembling limekilns; (3) Scott furnaces similar to those used in quicksilver metallurgy; and (4) rotary kilns, like those used in the manufacture of cement. To these may be added (5) mechanically rabbled furnaces of the Macdougal or Herreschoff type. In the rotary kilns, which probably represent the best cement calcining practice at present, all sizes may be calcined, fine as well as lump; but in the bottle-shaped kilns and the ordinary vertical kilns, only coarse lump magnesite can be clacined. At certain California mines the fines have been allowed to accumulate or have been treated separately in a Scott furnace.

The capacity of kilns varies according to the different types. The ordinary bottle-shaped kiln may produce 15 to 25 tons of calcine per 24 hours; vertical kilns yield 7 to 10 tons; and 125-foot rotary kilns, 60 to 75 tons per 24 hours.

In the bottle-type kilns producer gas is commonly used as fuel except in California where distillate or crude oil has been largely employed. Coke is sometimes used but it must be low ash as it is mixed directly with the crude magnesite. Powdered coal is generally used in the rotary kilns except in California where oil fuel is employed. In Germany and Austria brown coal is often used.

Caustic Calcining

The operation and control of kilns used in the calcination of magnesite to caustic magnesite are much the same as in lime-burning, but the temperature must not be allowed to exceed 1100° C., and with some varieties of magnesite an even lower temperature will result in overburning. More and more it is being recognized that in order to produce an oxychloride cement of uniform strength and standard good quality the material must be calcined at a fixed temperature and a definite rate. The rotary furnace affords a convenient means of regulating temperatures under careful pyrometric control. Details of the adaptation of a Scott quicksilver furnace to the burning of magnesite at the Maltby plant, near Livermore, Calif., have been described in detail by Riddell and

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Schuette[11] and considerable laboratory work has been done upon the production of caustic calcined magnesite in Herreschoff type furnaces. Furnace-fired lime kilns have been used in Canada, but difficulty was found in obtaining adequate temperature control.

Considerable work has been done upon methods of calcining varieties of magnesite containing relatively large amounts of lime. At temperatures below about 900° C. calcium carbonate is not decomposed and hence remains as an inert and harmless ingredient of the final product. In an ordinary kiln, however, it is difficult to control the partial pressure of CO_2 and thus maintain uniform conditions throughout the kiln which will bring about the desired result with sufficient certainty. To avoid these difficulties, the use of retorts has been proposed. In a suitable retort both temperature and pressure can be controlled within narrow limits and the pure carbon dioxide gas can be readily recovered.

Dead-Burning

In preparing magnesite for refractory uses the temperature of calcination is kept much higher than in producing caustic calcined magnesite. This is necessary (1) to render the product almost inactive to water vapor and (2) to shrink the material to a minimum volume so as to avoid cracking when used as a furnace lining. Magnesite that has been burnt sufficiently to keep well in storage usually is partially fused or fritted together, but it does not always follow that it has shrunk sufficiently to use in a high-temperature furnace. It seems probable that there is an α - magnesite (amorphous) having a specific gravity of about 3.2 which is changed by heating at a suitable temperature to a β - magnesite (crystalline) having a specific gravity of about 3.7 and being much more resistant to both chemical and physical disintegration. J. W. Mellor found that this change took place slowly but progressively at between 1300° and 1350° C. Commercial calcining, however, is done usually at temperatures varying from 1,500° C. (2,732° F.) for breunnerite to 1,700° C. (3,092° F.) for material low in iron oxide.

The presence of impurities exerts a profound influence upon the calcination. The presence of lime is a detriment, but within certain limits it may be counteracted by the addition of certain other impurities, especially iron oxide. The Styrian (Austrian) magnesite or breunnerite which generally contains about 7 per cent of iron oxide after burning has long been noted for the ease with which it can be dead-burned. On heating to a high temperature the impurity combines with lime in preference to magnesia, forming compounds that are inactive. The presence of iron also accelerates the change from one form of magnesia to the other and it is noteworthy that natural periclase nearly always contains a considerable quantity of iron[12] (or manganese oxide). Silica and alumina form similar compounds but their properties are not the same and they are not as suitable as iron oxide.

11 Riddell, W. C., and Schuette, C. N., The Production of Caustic Calcined Magnesite in the Scott Furnace: Eng. and Min. Jour.-Press, vol. 114, 1922, pp. 981-984.

12 Knibbs, N. V. S., Lime and magnesia: London, 1924, p. 203.

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Ordinary shaft kilns, fired by producer gas or of the mixed feed type, may be used in making dead-burned magnesite but they must be lined with magnesite brick in order to withstand the high temperature. The magnesite fed to vertical kilns is in 4 to 8 inch lumps, and the product drawn is sorted to remove impurities and incompletely dead-burned lumps. At the Broken Hill Proprietary Co.'s steel works in Australia, two forced-draught vertical shaft kilns, previously used as iron cupolas, are employed. These produce about 10 tons a day; they are worked alternately and consume about 320 to 400 pounds of coal per ton of calcine. The typical charge is 2½ tons of raw magnesite and 448 pounds (.4 cwt.) of coal, which is dumped into the charging bell.[13]

The stone for rotary kilns is generally crushed fine and this is especially necessary where blending is practiced. Canadian magnesite contains a considerable percentage of calcium carbonate and Washington and California magnesites have insufficient iron for ordinary dead-burning. It is therefore necessary to reduce the magnesite to a powder and to add from 2 to 5 per cent of finely-ground iron ore. Rotary kilns for dead-burning magnesite are lined in the burning zone with magnesite brick. Fuel consumption has been variously given as from 25 to 50 per cent of good coal (13,000 b.t.u.) but with good working conditions should not exceed 30 per cent.[14] The magnesite after being drawn from the kilns is quenched in water (or discharged upon a cooling floor) and crushed in rolls to pass 3/8-inch (grain magnesite).

In Austria the product of the shaft kilns is lightly crushed and then screened into three different sizes. Much of the quicklime and dolomite being quite soft are removed in the fine screenings. The oversize goes to picking tables where unburned magnesite, quartz, and other impurities are picked out by hand. After final crushing a second picking may be resorted to before the product is sacked. In recent years magnetic separators have been introduced; these are more economical of labor but do not recover magnesite that does not contain iron and hence are presumably employed only when a specially graded product is required.

California practice is described in the following abstract of a detailed description by Palmer:[15]

> At Red Mountain two sizes of stack kilns are in use, one type being 6 feet inside diameter with a capacity of 12 tons per 24 hours and the other 7 feet in diameter with a capacity of 14 tons. They are oil-fired, with fire-boxes built around the base, and they discharge to individual stacks, 2½ by 30 feet. A charge column of 18 feet is carried and the temperature ranges from 1800° to 2000° F. producing caustic calcined product in a period of 8 hours.

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13 Horn, N. H., Magnesite refractories: Chem. Eng. and Min. Review (Melbourne), vol. 21, April 5, 1929, pp. 261-265.
14 Knibbs, N. V. S., Page 204 of work cited.
15 Palmer, Leroy C., Page 753 of work cited.

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The Scott furnace made a satisfactory product but was discarded in favor of the rotary kiln because the latter had more capacity. At the Sampson mine in California the kiln is 80 feet long and is set with a pitch of 5 feet (1:16). The outside diameter of the shell is 7 feet and inside the lining the diameter is tapered from 6 feet at the discharging end to 4 feet at the stack end. For dead-burning, iron in the form of mill scale is added, and a temperature of 2800° F. is maintained in the fire zone (10 to 20 feet from the fire box) which receives an extra lining made by fusing 3 or 4 inches of magnesite dust onto the firebrick. The kiln makes one revolution in 80 seconds and has a capacity of 35 to 45 tons of dead-burned per 24 hours, according to whether the product is burned to a light brown or black.

Caustic calcine is produced in the same manner as dead-burned but at a lower temperature, 2200° F. in the fire zone, and thus requires no additional lining. Since the kiln can be fed more heavily the capacity for caustic calcine is 60 tons per 24 hours. It is interesting to note that when a kiln that has been making dead-burned is shut down and cooled, the first 30 feet (approximately) are found to contain dead-burned magnesite, after which there are 10 feet of over-burned caustic, and then 10 to 15 feet of good caustic, and the remainder raw ore. The grades do not merge but there is a sharp line of demarcation between them, indicating that the change takes place abruptly.

The kiln is oil-fired and consumes 60 gallons of fuel oil per ton of caustic and 70 gallons per ton of dead-burned. Labor consists of two men at the rotary on both day and night shift in addition to a crusher feeder, a blacksmith, a general utility man, and one man at each end of the aerial tramway on day shift.

MAGNESITE BRICKMAKING

In the United States magnesite brick is made both from domestic and Austrian magnesite but elsewhere Austrian magnesite or Czechoslovakian magnesite is chiefly used. It is essential in order to minimize burning shrinkage that the material be dead-burned to a high specific gravity. Numerous bonding materials such as caustic magnesite, serpentine, clay, and silicate of soda have been tried but were found unsatisfactory on account of the high burning shrinkage, reduction of refractoriness, or mechanical weakness of the brick. Temporary bonds - such as tar, molasses, and dextrine - are employed more or less in Europe to hold the particles together before burning, but in the United States the use of bonding material is not customary. The dead-burned magnesite, after being finely ground, is mixed thoroughly in a wet pan with a small amount of water and the bricks are then molded, usually in a power press. The green bricks are placed in rack cars and dried. In one American plant the bricks are fired in a tunnel kiln, but usually ordinary down-draft kilns are employed. Great care must be exercised in handling the unfired brick as they are quite fragile. The fragile nature of the brick not only increases the liability of breakage but also reduces the effective kiln capacity in many

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cases by about two-thirds; old silica brick and bats have to be laid in the kiln in order to support the magnesite. For this reason practically as much labor and fuel are expended in burning 30,000 brick as would be required for 90,000 if the green brick could sustain its own weight. The charging and discharging of these kilns takes about three weeks, of which time two weeks is actual firing time.

The tunnel kiln used by the Lavino Refractories Co. is 325 feet 6 inches long and is used for both chrome and magnesite brick. It has a capacity of 60 trucks, each holding a maximum of 864 brick, the daily throughput being approximately 12,000 bricks. The maximum temperature in the kiln is 2,800° F. as it leaves the hot zone and 600 to 700° F. as it leaves the kiln. The kiln is direct fired, using 528 B.t.u. city gas fuel. Temperatures are carefully controlled; 12 recording pyrometers of radiation type are used to give the temperature of the ware as it passes through the furnace zone, and kiln temperatures at various points are measured by 12 thermocouples instruments. In addition, the maximum kiln temperature reached in the furnace zone is indicated by means of pyrometric cones placed in each car.[16]

In an effort to avoid the expense of producing fired brick, unburned brick are now on the market. Various patents have been issued during recent years for producing magnesite brick and sundry molded articles. In one process linseed oil is used to hold the magnesite together until it is burned into place. Schlotterer and Youngman have been issued a patent (U. S. Patent 1643181, September 20, 1927) for forming unburned refractory brick from mixtures of dead-burned magnesite and powdered sodium silicate (5 to 10 per cent); the mixture is moistened, formed, and dried carefully and slowly at only slightly above ordinary temperatures. Metal-cased brick is formed by ramming magnesite into short lengths of old 3-inch boiler tubes or rectangular steel containers.

Data regarding Eurpoean practice and a different procedure used in Australia are given by Horn:[17]

> In Europe, the dead-burned magnesite, after crushing and sorting is ground in edge-runner or ball mills to 1/16 in. The specific gravity is often obtained to give an indication of the amount of shrinkage likely to occur and to permit of definite volume weight to be made from material of different batches. The ground mass is moistened with 4-5 per cent of water, sometimes, though not usually, with the addition of dextrine or similar binder, and mixed in a trough mixer or pan mill. In some cases it is allowed to stand for two days to three weeks before pressing.

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16 Housman, George S., and Seil, Gilbert E., Modern Practice Crystallized in New Tunnel Kiln: Chem. and Met. Eng. vol. 36, June, 1929, pp. 340-343.

17 Horn, N. H., Magnesite Refractories: Chem. Eng. and Min. Review, Melbourne, vol. 21, April 5, 1929, pp. 261-265.

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It is moulded in a hydraulic press at 3,500-7,000 lb. per sq. in., depending on the character of the magnesite used and its difficulty of sintering. Easily sintered material is given the lower pressure. The "green" bricks are slowly dried, sometimes in dryers heated by waste steam, at others in well ventilated sheds heated only in winter. The maximum burning temperature is maintained 24 hours; it is usually about cone 18 (1,500 deg. C.). It is stated that bricks burned to cone 30-34 (1,670-1,750 deg. C.) shrink to such an extent that they can be used in furnace arches. * * * * * * *

The method adopted at the magnesite brick plant of the Broken Hill Pty. Co. Ltd. is essentially different to both the American and European practice, in that in our case the brick may be said to be made direct from the raw magnesite. The procedure is as follows: The raw Attunga magnesite is passed through a jaw cracker and crushed to 2-2½ in. size. From the jaw cracker it is fed to a wet grinding edge runner pan and ground to a stiff paste of the following representative fineness of grind:- On 1/8-in. screen, 6.85 per cent; on 16, 16.55 per cent; on 20, 4.92 per cent; on 40, 10.68 per cent; on 60, 9.70 per cent; through 60, 51.30 per cent. Total, 100.00 per cent.

This paste is passed through a "wire cut" machine cutting nine roughly standard size brick at a time and turning out on an average 1,200 bricks per hour. The wire cut brick is stacked in hacks for 3-7 days to dry, the drying being facilitated by the rough and open edge cut by the wires. These bricks are burned in a down draught kiln fired with coal for 96 hours for the last eight hours of which they are allowed to "soak" at 1,200 deg. C. No cone is used, the temperature being judged by the eye. The burning is arranged to finish on Friday midnight, allowing the kiln to cool off and be discharged on Monday morning. These so-called "first burn" bricks are very misshapen and considerably reduced in size; the volume shrinkage amounts to about 40 per cent. The first burn bricks are then ground in batches of 770-800 lb. in wet grinding pans for 20-25 minutes with the addition of sufficient water to form a stiff paste, and 15 lb. of roll scale is also added. Batches of this material are placed on the floor and allowed to stand overnight to "mellow" and reground the next day for 10-15 minutes, with a further addition of 10 lb. roll scale. The mellowing overnight is considered to facilitate grinding and give a better product. Representative sizing analyses of the two grinds (a) and (b) are as follows:- On 1/8-in. screen, (a) .23, (b) .11 per cent; on 16, (a) 10.62, (b) 3.25 per cent; on 20, (a) 4.67, (b) 5.81 per cent; on 40, (a) 12.05, (b) 12.06 per cent; on 60, (a) 16.40, (b) 15.57 per cent; through 60, (a) 56.03, (b) 63.20 per cent.

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Fine grinding makes a dense brick, but the temperature of the first burn is of equal, if not more, importance. The second ground material is then hand moulded in steel moulds to size and allowed to stand overnight on the floor; they are picked up next morning and pressed in a manual press; standards only are pressed as there are no dies for shaped bricks owing to the small quantity made.

The bricks are stacked uniformly, after pressing, in hacks of about 13,000, and allowed to stand for about a week when the bricks are "skintled," i.e., rearranged in stacks in zigzag and staggered formation to allow of a good circulation of air for drying. The "skintled" stacks are allowed to stand for a fortnight after which the bricks are ready for burning. The bricks are burnt in a rectangular down draught kiln smaller than the kiln used for the first burn brick. About 13,000 are burnt at a time, set 16 courses on edge high. Cone 14 is placed in bottom of kiln and cone 16 on top. The burning takes about 96 hours and when the cone 16 are melted down at both ends, the damper is lowered right down and the fireholes ashed up and sealed tight to prevent ingress of air which would crack the bricks. The kiln is banked thus for three days until black-looking through peep-holes, when the kiln is ready for "dragging."

WORLD PRODUCTION

Until 1914, Austria-Hungary and Greece supplied the bulk of the world's magnesite but the list of producing countries has been greatly enlarged in later years. Of the pre-war output of Austria-Hungary, about 75 per cent was produced in Austria and 25 per cent in what is now Czechoslovakia. These Succession States and Greece still furnish a large output, but they do not produce quite so large a tonnage as in 1913, so that since world demands have increased they are relatively less important. Other countries, like the United States, have increased production and several new fields have been opened. Still other fields await a further increase in demand before they can be exploited commercially. Magnesite is not an uncommon mineral and deposits of considerable size exist in many parts of the world.

When exports from Austria were cut off as a result of the outbreak of hostilities in Europe, Greece, which had hitherto supplied magnesite chiefly to the chemical and plastic cement trade, was called upon to furnish material for refractory purposes. Even before the war British India had become of some importance as a source of magnesite and California and New South Wales and to a minor extent Italy, Norway, Spain, and South Africa were producing magnesite, largely for local consumption. As the war continued, the industry in all these lesser localities was expanded. The largest increase in production was in the United States but Canada, Italy, Australia, and, for a time, Russia likewise contributed heavily toward making up the deficit in supplies outside of the territory held by the Central Powers.

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After the Armistice in 1918 the resumption of large-scale mining in Austria and Czechoslovakia was delayed for several years because of internal conditions and because of the general dislocation of the European steel industry. Meanwhile tariff protection was accorded the newly-developed industry in the United States, the world's largest single market, and magnesite mining in several other countries became better entrenched, at least with respect to nearby markets. For mutual protection the producers in Czechoslovakia and Austria are united in a cartel, but they have lost their former dominance of the world situation. Large increases in Russian exports and developments in other fields - as for example Jugoslavia which first reported production in 1927 - would tend to indicate a continued decentralization of the industry.

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World production of crude magnesite, 1901-1928, by countries, in metric tons[1]
(Compiled by K. G. Warner of the Bureau of Mines)

Country	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910
Australia:										
New South Wales..	--	--	--	--	--	--	--	--	2/ 80	--
Queensland	--	--	--	--	--	--	--	--	--	--
South Australia..	--	--	--	--	--	--	--	--	--	--
Victoria	--	--	--	--	--	--	--	--	--	--
Western Australia	--	--	--	--	--	--	--	--	--	--
Austria[3].....	4/84,496	4/112,281	4/145,022	4/112,940	4/193,954	4/184,307	4/239,212	4/183,015	4/264,926	4/384,454
Canada	--	--	--	--	--	--	32	109	299	293
Cyprus	--	--	--	--	--	--	--	--	--	--
Czechoslovakia ...	--	--	--	--	--	--	--	--	--	--
Greece	20,348	23,020	28,415	9,133	37,063	40,584	55,816	63,079	56,797	18,073
India, British ...	6/	3,597	838	1,193	2,645	1,861	138	7,655	199	5,264
Italy	4,700	3,863	1,000	830	625	1,330	1,200	1,200	1,020	920
Norway[9]	--	--	--	--	--	--	--	--	--	--
Russia	--	--	--	--	--	--	--	--	--	--
Spain	--	100	2,260	1,129	1,446	1,335	1,954	996	850	277
Union of So.Africa	--	--	--	--	--	11/ 230	11/ 943	11/ 256	11/ 374	11/ 479
United States (sold or treated)	3,175	2,567	3,396	2,585	3,568	7,081	6,859	5,976	8,586	11,284
Venezuela[4]	--	--	--	--	--	--	--	--	--	--
Yugoslavia[12]	--	--	--	--	--	--	--	--	--	--
Total[13]	112,719	145,428	180,931	127,810	239,301	236,728	306,204	262,286	333,131	421,045

1/ Data mainly from Mineral Industry (Annual) for the years 1901-1912, and Mineral Resources of the United States (Annual), Geological Survey and Bureau of Mines, for 1913-1928. 2/ Raised but not disposed of, and is probably included in later totals. 3/ Austria Hungary prior to 1919. 4/ Exports. 5/ Exports of crude and calcined magnesite, the latter being reduced on the basis of 2.1 tons crude to 1 ton calcined. 6/ Data not available. 7/ Exports from the Republic of Austria for second half of 1919. 8/ Exports less imports, of crude and sintered magnesite, the sintered being reduced to crude on the basis of 2.1 tons crude to 1 ton sintered. 9/ In addition to exports of crude magnesite shown for 1913-1921, there was exported magnesite brick (magnesittegel) as follows: 1913, 626 tons; 1914, 494 tons; 1915, 729 tons; 1916, 519 tons; 1917, 341 tons; 1918, 355 tons; 1919, 357 tons; 1920 710 tons; 1921, 337 tons. 10/ Year ended Sept. 30. 11/ Fiscal year ending June 30; 249 tons reported the last six months of the calendar year 1910. 12/ Serbia only. 13/ Does not include magnesite produced in countries for which production statistics are not available.

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World production of crude magnesite, 1901-1928, by countries, in metric tons[1] - Continued
(Compiled by K. G. Warner of the Bureau of Mines)

Country	1911	1912	1913	1914	1915	1916	1917	1918	1919
Australia:									
New South Wales ..	2/ 150	2/ 5,700	7,112	2,032	843	3,821	9,337	3,419	9,413
Queensland	--	--	--	--	--	--	--	--	--
South Australia ..	--	--	--	--	81	169	152	447	277
Victoria	166	211	106	23	192	30	75	229	78
Western Australia.	--	--	--	--	612	100	21	107	--
Austria[3]	4/384,190	4/359,512	5/422,439	5/279,651	5/78,314	5/81,771	5/106,783	6/	7/59,486
Canada	899	1,555	467	325	16,475	51,981	58,755	52,434	13,564
Cyprus	--	--	--	--	15	15	6/	6/	6/
Czechoslovakia	--	--	--	--	--	--	--	--	--
Greece	86,956	106,338	98,517	136,701	159,981	199,484	162,938	38,340	62,408
India, British	3,546	15,626	16,458	1,707	7,569	17,922	18,493	5,947	17,401
Italy	360	400	600	1,140	9,200	18,252	31,070	28,332	35,930
Norway[9]	--	--	4/ 656	4/ 938	5/ 4,017	5/ 3,499	5/ 1,004	5/ 542	5/ 1,882
Russia	--	--	60,617	--	6/	72,074	73,712	19,656	6/
Spain	1,400	1,430	958	583	1,400	2,500	800	1,700	120
Union of So. Africa	319	546	403	519	569	553	709	756	929
United States (sold or treated)	8,505	9,536	8,738	10,245	27,668	140,589	287,429	210,107	141,725
Venezuela[4]	--	--	2,000	300	5,300	6,360	1,700	--	--
Yugoslavia[12]	--	--	--	--	--	--	--	--	--
Total[13]	486,491	500,904	619,071	434,164	312,236	599,120	752,978	363,566	343,213

For footnotes see page 19.

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World production of crude magnesite, 1901-1928, by countries, in metric tons[1] - Continued
(Compiled by K. G. Warner of the Bureau of Mines)

Country	1920	1921	1922	1923	1924	1925	1926	1927	1928
Australia:									
New South Wales...	6,578	12,465	3,424	6,228	12,697	14,237	10,428	10,178	10,840
Queensland	--	--	--	--	151	271	--	--	--
South Australia...	188	175	585	168	131	357	230	335	46
Victoria	153	130	99	76	77	92	96	73	73
Western Australia.	--	--	--	4/ 2	--	--	--	--	--
Austria[3]	5/135,312	5/178,152	5/307,781	5/191,508	5/170,373	290,000	237,000	356,000	310,000
Canada	28,159	8,447	7,873	12,079	9,512	3,827	11,429	18,523	25,137
Cyprus	6/	305	4/ 895	4/ 284	4/ 224	--	4/ 83	4/ 16	--
Czechoslovakia	--	8/ 48,578	8/ 92,942	8/ 64,030	8/ 60,044	8/ 69,532	8/ 83,135	8/ 84,563	8/ 87,396
Greece	71,870	60,132	56,642	62,552	66,727	90,828	95,638	84,484	104,421
India, British	14,577	20,338	19,582	19,748	24,854	30,095	30,960	19,953	24,798
Italy	33,850	9,410	8,700	12,474	13,436	14,146	19,842	16,304	11,690
Norway[9]	5/ 2,041	5/ 210	738	2,359	1,976	1,699	715	1,090	932
Russia	17,984	14,915	10,909	10/18,445	10/33,214	10/75,840	10/103,017	10/106,583	10/120,000
Spain	1,214	--	303	--	--	--	--	--	--
Union of So. Africa	1,287	1,803	997	1,387	2,001	1,823	1,884	1,839	1,481
United States (sold or treated)	275,571	43,458	50,612	133,582	108,952	109,460	121,109	110,213	115,393
Venezuela[4]	2,000	2,400	--	--	--	--	--	--	--
Yugoslavia[12]	--	--	--	--	--	--	--	1,680	6,267
Total[13]	590,784	400,918	562,082	524,922	504,369	702,207	715,556	811,834	818,474

For footnotes see page 19.

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DOMESTIC PRODUCTION AND DEPOSITS

Important deposits of magnesite have been located in only three States (California, Washington, and Nevada) and only two (California and Washington) have actually furnished any commercial production. A brucite deposit in Nevada may also be mentioned as being a possible source of high-magnesium material. Occurrences in other States have apparently never been utilized.

The production of magnesite in the United States began in California in 1886 when several carloads or tons of magnesite were shipped to New York from deposits on Cedar Mountain, Alameda County, Calif. In 1891, 439 tons were produced by California mines and beginning in the following year the output continued at the rate of somewhat more than 1,000 tons annually until 1900 when it started to rise slowly to a maximum of 12,443 tons in 1910,[18] all of which was actually sold in the caustic calcined condition. Much of this quantity was used by paper manufacturers in California and Oregon but increasing quantities were demanded by the makers of artificial stone, tiling, flooring, and other building materials.

For the five-year period, 1910-1914 inclusive, the average output of domestic magnesite, expressed as crude, was 10,651 tons annually, all of which came from California and all of which was consumed west of the Rocky Mountains. In 1915 as the shortage of foreign supplies began to be felt the production of California mines was practically trebled and in December, 1916, the newly opened Washington deposits came into production. In 1918 the record quantity of 316,838 tons valued at $2,899,818 was produced much of which was marketed as dead-burned material for refractory uses. In 1918 while the production from Washington continued to increase there was a sharp curtailment in California. The shortage of cars operated to restrict shipments to eastern consumers but the main cause for the falling off in California production was that the refractory companies stopped buying crude magnesite in the fall of 1917, the freight charges being so much greater than on dead-burned material having only about one-half the weight. Since many of the California producers were not equipped with kilns they lost business. Imports from Canada and the preference for crystalline magnesite instead of the amorphous product of California mines were other factors.

After the Armistice in 1918, the steel companies expecting an early resumption of imports of Austrian magnesite, practically ceased buying until 1920 when, foreign supplies still being unavailable, they were forced to buy domestic magnesite--despite its relatively high cost due to the long freight haul from western mines to eastern consuming points. As the steel industry emerged from the depression of 1921, the competitive position of the Washington producers of dead-burned material was improved by the duties levied under the

18 In that year one of the active mining companies also mined 2,272 tons of what was called "magnesite clay", worth $10 a ton when pulverized.

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tariff act of 1922. About the same time the demand for caustic calcined magnesite began to take on the proportions of a boom and the production from California mines increased temporarily, only to drop off again after a year or two to somewhat lower levels.

Since 1926, the California producers have succeeded in making up some of their losses in sales of caustic calcined magnesite by increasing their output of dead-burned material, including both ordinary dead-burned and special refractory material such as artificial "periclase".

Domestic magnesite (expressed as equivalent crude) sold or treated in the United States, 1891-1929

(Data from Mineral Resources of the United States)

Year	Short tons	Value	Year	Short tons	Value
1891	439	$ 4,390	1911	9,375	$ 75,000
1892	1,004	10,040	1912	10,512	84,096
1893	704	7,040	1913	9,632	77,056
1894	1,440	10,240	1914	11,293	124,223
1895	2,220	17,000	1915	30,499	274,491
1896	1,500	11,000	1916	154,974	1,393,693
1897	1,143	13,671	1917	316,838	2,899,818
1898	1,263	19,075	1918	231,605	1,812,601
1899	1,280	18,480	1919	156,226	1,248,415
1900	2,252	19,333	1920	303,767	2,748,150
1901	3,500	10,500	1921	47,904	510,177
1902	2,830	8,490	1922	55,790	571,745
1903	3,744	10,595	1923	147,250	1,103,700
1904	2,850	9,298	1924	120,100	1,041,300
1905	3,933	15,221	1925	120,360	1,432,700
1906	7,805	23,415	1926	133,500	1,200,830
1907	7,561	22,683	1927	121,490	1,090,550
1908	6,587	19,761	1928	127,200	1,098,550
1909	9,465	37,860	1929	187,657	1,501,256
1910	12,443	74,658			

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Production of Crude Magnesite, by States, 1916-1929

(Data from Mineral Resources of the United States)

	California		Washington		Total	
	Short tons	Value	Short tons	Value	Short tons	Value
1916[1]	154,259	$1,388,331	715	$ 5,362	154,974	$1,393,693
1917	211,663	2,116,630	105,175	783,188	316,838	2,899,818
1918	84,077	761,811	147,528	1,050,790	231,605	1,812,601
1919	50,020	504,973	106,206	743,442	156,226	1,248,415
1920	81,782	1,083,262	221,985	1,664,888	303,767	2,748,150
1921	47,900	510,140	- -	- -	47,900	510,140
1922	55,610	570,000	180	1,800	55,790	571,800
1923	73,350	953,550	73,900	169,970	147,250	1,123,520
1924	67,240	901,020	52,860	129,510	120,100	1,030,530
1925	64,600	872,100	56,060	560,600	120,660	1,432,700
1926	53,940	604,130	79,560	596,700	133,500	1,200,830
1927	43,750	507,500	77,740	583,050	121,490	1,090,550
1928	41,300		85,890		127,200	1,098,550
1929	(2)	(2)	(2)	(2)	187,657	1,500,000

1/ Prior to December 1916, California was the only producing State.
2/ Bureau of Mines is not at liberty to publish separate figures by States in 1929.

Marketed production of domestic magnesite by kinds, 1922-1929[1]

(Data from Mineral Resources of the United States)

Year	Crude			Caustic calcined			Dead-burned		
	Short tons	Value		Short tons	Value		Short tons	Value	
		Total	Average		Total	Average		Total	Average
1922	1,300	$13,330	$10.25	21,990	$ 813,630	$37.00	2,200	$ 51,260	$23.30
1923	6,020	78,260	13.00	28,470	1,035,740	36.38	34,410	671,000	19.50
1924	1,570	20,410	13.00	26,520	883,120	33.30	29,830	787,500	26.40
1925	2,090	26,290	12.58	23,900	782,700	32.75	29,110	923,960	31.74
1926	1,540	17,440	11.32	18,580	596,370	32.10	42,540	1,089,680	25.62
1927	1,800	17,130	9.52	13,890	452,810	32.60	40,210	990,300	24.63
1928	620	5,690	9.18	13,310	454,820	34.17	45,230	1,076,310	23.80
1929	--	--	--	11,390	(2)		78,700	(2)	

1/ Prior to 1922, no distinction was made in statistics between caustic and dead-burned magnesite.
2/ The Bureau of Mines is not at liberty to publish values for caustic calcined and dead-burned magnesite separately for 1929. The total value of such sales was $1,947,860.

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California[19]

The California magnesite is of the amorphous type. Deposits occur in numerous localities throughout the Coast Ranges and on the west slope of the Sierras, from Mendocino and Placer Counties on the north to Riverside County on the south. In nine counties the deposits are large, while in four counties only small deposits have been found. With only two notable exceptions all the California magnesite deposits occur as irregular veins, lenses, masses, or stock work in serpentine rock. In a few places the veins or masses are 20 feet or more in width, but generally the veins are narrow and separate lenses are irregularly disposed. At Bissell, Kern County, and at Afton, San Bernardino County, the magnesite is of sedimentary origin. Several thousand tons have been shipped from the former property, and small shipments have been made from the latter.

In the early years production was confined almost exclusively to Tulare County, and this county until some time after the war (1921) headed the list of producing counties year after year. Even in 1917 when new mines were working all over the State, Tulare County contributed 63 per cent of California output and in 1920, another boom year, it furnished 41 per cent. Santa Clara County, also an important producer even before the war, has in recent years produced more magnesite than Tulare County. In 1929, magnesite was also mined in Stanislaus County and in San Benito County. In 1917 Napa County was second only to Tulare County in point of production, furnishing 40,209 out of a total of 211,663 tons produced in the entire State; much of the output was natural ferro-magnesite and hence was in great demand for refractory purposes, but with the resumption of imports of Austrian material, production in this county dropped off rapidly, and in recent years most of the mines have been virtually abandoned.

Since about 1920 the largest production of magnesite in California has come from the Red Mountain mine in Santa Clara County, operated by C. S. Maltby. The magnesite deposits at Red Mountain and those at Sampson Creek in San Benito County formerly worked by the same operator, together with details of the methods of mining, calcining, and handling the material, have been described by Palmer[20]. The Red Mountain property is situated near the junction of Alameda, Stanislaus, and San Benito Counties and 32 miles from Livermore on one of the main lines of the Southern Pacific Railroad. Ore has been shipped from four groups of workings but more recently work has been concentrated at the White Queen and White Diamond mines which are served by aerial tramways that converge to a central calcining plant. The mines are well up on the side of a steep mountain and the workings, originally open-cut, are now underground.

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19 For further description see U. S. Geol. Survey Bull. 355: Magnesite deposits of California, by F. L. Hess, 1908; U. S. Geol. Survey Bull. 540-5: Late developments of magnesite deposits in California, by H. S. Gale, 1913; various chapters of Mineral Resources of the United States; and Calif. State Min. Bur. Bull. 79: Magnesite in California, by W. W. Bradley, 1925.

20 Palmer, Leroy C., Magnesite Mining in California: Trans. Am. Inst. Min. and Met. Eng., vol. 75, 1927, pp. 743-756.

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Four vertical kilns are used for calcining lump ore, and a rotary kiln treats fines, replacing the Scott furnace formerly used for that purpose. The deposits occur along fracture zones in serpentine running practically due north and south. The dips vary widely but average 45 to 50°, usually to the west. The stopes vary from 6 to 15 feet in width, averaging 10 feet. Extreme widths reach 40 feet but this is rare, and often the mineralized area narrows to a mere stringer. Horizontally the ore is likely to open out again after a pinch but at depth this condition is considered an indication that the lower limit of the ore-body is being reached. The deposit has been opened up over an area of several thousand feet in both length and width. A large number of veins have been encountered and the deposit is known to be of unusual size, although the extent of the ore reserves has not been explored because the surface is covered with a growth of brush that is literally impenetrable.

The Sierra Magnesite Co., (S. H. Barrows, president) the second largest producer in California, operates a group of mines including the Rex, Lindsay, Tulare, and Gill ranch mines, mostly in the vicinity of Magnesite, Tulare County, 12 miles east of Porterville where it maintains an up-to-date calcining plant producing both caustic calcined and a special grade of dead-burned magnesite ("periclase") in two rotary kilns. In 1929 it also had undertaken production at a property in Stanislaus County, about 20 miles west of Ingomar.

The California Magnesite Co., operates a mine on Red Mountain, not far from the Maltby property but over the line in Stanislaus County, west of Patterson; it produces calcined magnesite (for magnesia heat insulation and for flooring and stucco) from one upright kiln.

The Sampson Magnesite Co. came into production of dead-burned magnesite in 1928 at the Sampson Peak property, San Benito County, operated for some time by C. S. Maltby. Road conditions on the 60-mile haul to Mendota (northeast) were given as the reasons for discontinuing operations in October, 1926; the mine is said to contain large reserves of ore and is only partly developed.

In 1929, F. M. Nevins reported the extraction of a considerable tonnage of magnesite in development work at Parkfield, near Coalinga, Monterey County; no magnesite was sold, but roads were built so that shipments could be made later. Prospecting was in progress at various other localities but no production was reported in 1929 except from the operators named above. During the war and again during the 1920 boom much of the production was from small mines, often worked by farmers. Many of these mines were situated at considerable distances from railroad shipping points and were handicapped by excessive hauling charges as well as high mining costs.

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Washington

In Washington the magnesite is of the crystalline variety. In fact one or two of the principal deposits were first worked as marble quarries; some $100,000 worth of stone was sawed, polished, and sold from the Keystone deposit by the U. S. Marble Co. between 1898 to 1903. Deposits have been found in several localities in the northeastern part of the State (Stevens County), about 60 miles north of Spokane and 5 to 12 miles west of Valley and Chewelah. The magnesite occurs massive; the larger deposits are 300 or more feet thick and 1,000 or more feet long. They are of sedimentary origin and evidently were formed by the replacement of dolomite lenses. The material ranges from fine-grained to coarse, and is gray, white, black, pink, or red.

The production of magnesite in Washington was begun in December, 1916, by the Washington Magnesite Co., which in the following year became the Northwest Magnesite Co., which is now the only operator. The principal holdings of the company are the Finch deposit and a calcining plant at Chewelah. The Finch mine is within about 5 miles of Chewelah and has furnished by far the largest part of the magnesite output of the State. Originally opened as a quarry the Finch ore body was later found to have been faulted and an underground mine and quarry on the opposite side of the hill were started in the main deposit. The Keystone deposit, 10 miles by road west of Valley, was also included in the original holdings of the company but has not been worked, at least extensively, since 1917, because it is somewhat further from the calcining plant than the Finch mine.

Early in 1917 the American Mineral Products Co. acquired three magnesite deposits west of Valley and after carrying on some vigorous development shipped a considerable quantity of both crude and calcined material during the first year. Much of the output of this company was from the Allen and Moss quarries situated 7 miles northwest of Valley on the western side of Browns Lake and less than 1 mile from the Finch quarry which lies to the north. The Allen quarry and the Moss quarry were opened at the north and south ends, respectively, of a magnesite lens about a quarter of a mile long. Four vertical brick kilns were built nearby for calcining the material. Two more kilns were erected by the company at the Woodbury deposit about 1½ miles southwest of the Allen quarry and only 6 miles from Valley, but they were operated only a short time as it was found impracticable to produce at this deposit ore sufficiently free from silica and dolomite. The third deposit owned by the American Mineral Production Co. had previously been prospected as a marble property and because of the color is known as the Red Marble deposit. It is evidently at least a quarter of a mile long and 200 to 300 feet wide and indications pointed to the fact that 1,000,000 tons or more of saleable magnesite could be mined within the first 50 feet below the surface. Transportation conditions were unfavorable, however, the ore occurring along the crest of a ridge 900 feet above Deer Creek and 12 miles west of Valley, necessitating the building of an aerial tram and a branch railway.

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The Valley Magnesite Co. was another war-time operator, producing both crude and calcined magnesite from the Double Eagle quarry and kilns situated about halfway between the Keystone and Red Marble deposits. The cost of hauling the product by wagon or autotruck over the rough road 12 miles to Valley was $4.50 a ton in 1917.[21] The magnesite in this deposit is mostly black and white. This company was succeeded by the Western Materials Co.

In addition to the companies mentioned several smaller operators were in the field during and shortly after the war, but in 1921 production ceased entirely due to the general slackness in the steel industry and increased supplies of imported material. Late in 1923, as the industry began to revive, the Northwest Magnesite Co. purchased the three mines of the American Mineral Production Co. and has since become the only surviving operator in the field. In 1930 it was made public that the Northwest Magnesite Co. was jointly owned by the Harbison Walker Refractories Co. and the General Refractories Co. The calcining equipment comprises six rotary kilns, electrically controlled and fired with powdered coal. Recently (1929-30) a plant was built for making Thermax (heraklith) fireproofing material.

Nevada

According to Yale[22] a large deposit found in Clark County, Nev., on Muddy River, near St. Thomas contains magnesite high in lime and silica and another deposit of magnesite has been reported near Goldfield. A press bulletin issued by the United States Geological Survey and quoted by Hill and Loughlin[23] states that the deposit of the Nevada Magnesite Co. in the valley of the Muddy River, a few miles above the town of St. Thomas, "promises to yield a large and readily available supply of this material." The material is described as porcelain-white, fine-grained, massive, and remarkable free from foreign material. It has the structureless appearance and conchoidal fracture generally characteristic of magnesite, but since it is softer than typical magnesite and since it crumbles rapidly on exposure to the weather it was originally thought to be kaolin. The deposit forms a chalky white bluff, dazzlingly white in bright sunlight, and the purer portion consists of beds aggregating 200 feet thick.

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21 Yale, C. G., and Stone, R. W., Magnesite in 1917: Mineral Resources of the United States, Part 2, 1917, U. S. Geol. Survey, p. 75.

22 Yale, Chas. G., Magnesite: Mineral Resources of the United States, 1915, Part 2, U. S. Geol. Survey, p. 1024.

23 Hill, J. M., and Loughlin, G. F., Magnesite: Mineral Resources of the United States, 1922, Part 2, U. S. Geol. Survey, p. 47.

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No magnesite appears to have been produced commercially in Nevada but during 1927 a deposit of brucite (magnesium hydrate) was discovered on the west slope of Paradise Mountains in Nye County, 30 miles north of Luning, on a contact of granite with dolomite. This deposit is reported to be very extensive and quite pure. A carload of this material was shipped in 1929 for testing purposes and it is reported that the brucite can be used commerically. Since transportation difficulties are not serious, this occurrence may become a factor in the domestic supply of magnesia products.

Other States

A deposit of magnesite on a steep hillside west of Ash Creek, 2 miles above its junction with the Gila River, about 30 miles north of Lordsburg, N. Mex., was examined by R. W. Stone of the United States Geological Survey in May, 1920, and described in the chapter on magnesite in Mineral Resources of the United States for 1919 (Part 2, p. 234). The magnesite is hard, amorphous, and pure white, resembling California material, but it occurs in detached blocks of limestone, none of them more than a few rods long, inclosed in granite and cut by dikes and sills of diabase (older than the granite). The best exposure shows only 7 feet of magnesite in a limestone block 5 or 6 rods long, and some of the limestone blocks contain no magnesite. In view of the small quantity of magnesite available and the distance from the railroad the occurrence was considered to have little present commercial value.

Magnesite occurrences have been reported in several Eastern States including New York, New Jersey, Pennsylvania, Massachusetts, and Maryland but in view of the fact that no active efforts to exploit them have been reported, even in war time, the assumption seems warranted that they are of no commercial significance.

IMPORTS

As previously noted, practically all the domestic supply of dead-burned magnesite for refractory purposes was formerly exported from Austria and the major part of the crude and caustic calcined material used for other purposes was of Grecian origin. Most of the pre-war importations of calcined magnesite from the Netherlands, Belgium, Germany, and even the United Kingdom consisted of reexported Grecian magnesite, calcined or merely repacked in those countries. A part of the imports from the United Kingdom (Scotland), however, was of Norwegian origin.

Prior to the tariff act of 1922 the import statistics showed only two classes of magnesite - crude and calcined. No distinction was made between dead-burned and caustic calcined magnesite but since the countries of origin are noted it appears that for the five-year period preceding the outbreak of the war in Europe (fiscal years 1910-1914) almost 95 per cent of the imports recorded as "calcined magnesite, not purified" were from Austria-Hungary and hance consisted probably of dead-burned material. The proportion of magnesite

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imported raw showed a gradual falling off, even before the war. In 1902, the first year for which separate statistics are available, the weight of the crude magnesite imported was about one-half as great as the weight of the calcined imported, but by 1914 the proportion had dropped to less than one-thirteenth. During the fiscal year ending June 30, 1914, almost 150,000 tons of calcined magnesite, valued at $1,500,000 was imported into the United States, more than five times the quantity imported in 1904. On the other hand, the 11,000 tons of raw magnesite imported in 1914 was less than the annual importation a decade before.

The tendency to ship the material in the lightest (calcined) form was interrupted when the war first cut off the importation of Austrian dead-burned and for a time a much larger proportion of crude magnesite was imported. No other European country had sufficient idle calcining facilities to take care of the sudden increase in demand and due in part to the disruption of established trade routes even some of the Grecian magnesite, ordinarily calcined in Europe en route, was shipped to the United States in crude condition. Later crude magnesite began to come from Canada, and in 1917 (fiscal year) the importation of crude magnesite was the largest on record as regards both quantity and value, amounting to nearly 90,000 tons valued at $750,000 -- 9 times the quantity and 16 times the value of the 1914 imports. The year ending June 30, 1917, also marks the minimum importation of calcined magnesite -- less than 5,000 tons, valued at only $182,000, or less than one-thirtieth of the amount and about one-eighth the value of the 1914 imports.

After the war, imports did not begin in volume again until 1922, and even in that year a somewhat larger tonnage of crude than of calcined magnesite was imported. The incidence of the new duties under the tariff act of 1922 hastened the elimination of imports of crude magnesite and checked the growth of imports of dead-burned material. The imports of caustic calcined magnesite, on the other hand, increased, reaching a maximum of 17,075 tons in 1925. An advance in duty on such material under the so-called "flexible tariff" combined with the reduced demand caused the imports under this category to drop off to 5,474 tons in 1928.

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Magnesite Imported for Consumption in the United States[1]

Year	Crude		Calcined	
	Short tons	Value	Short tons	Value
1901	(2)	$ --	2/ 33,461	$ --
1902	(2)	--	2/ 49,786	373,928
1903	18,009	150,002	36,767	311,396
1904	15,133	83,012	23,572	203,816
1905	7,076	63,264	67,298	575,355
1906	19,739	122,908	70,657	740,585
1907	23,439	186,988	75,569	688,371
1908	19,763	81,518	64,731	655,245
1909	9,818	46,005	104,474	939,014
1910	26,001	162,069	148,826	1,380,731
1911	12,974	76,097	122,075	1,109,770
1912	17,905	104,326	125,252	1,265,339
1913	13,240	84,911	167,094	1,672,565
1914	13,354	54,677	121,817	1,323,194
1915	49,764	255,140	26,574	232,071
1916	75,345	634,447	9,270	204,183
1917	30,277	232,105	3,966	232,601
1918	5,432	103,233	19,049	824,022
1919	6,381	103,311	9,471	270,721
1920	33,550	406,204	14,780	373,165
1921	51,993	525,452	6,788	250,932
1922	73,331	976,283	72,265	1,267,622
1923	5,182	44,081	72,955	1,022,968
1924	6	85	64,785	1,172,403
1925	487	6,382	68,395	1,160,830
1926	608	6,555	90,293	1,438,765
1927	856	8,574	59,261	946,361
1928	762	6,264	62,481	966,183
1929	300	3,179	56,879	877,090

1/ Data from annual chapters of Mineral Resources of the United States, Part 2,
2/ Crude included with calcined.

TARIFF DUTIES

Prior to Sept. 22, 1922, "magnesite, crude or calcined, not purified" was specifically mentioned as free of duty. The act of 1922 (par. 204) provides duties as follows: Crude magnesite, five-sixteenths of 1 cent per pound; caustic calcined magnesite, five-eights of 1 cent per pound; dead-burned and grain magnesite, not suitable for manufacture into oxychloride cements, twenty-three fortieths of 1 cent per pound. By Presidential proclamation, effective December 9, 1927, and following an investigation by the United States Tariff Commission, the duty on caustic calcined magnesite was increased to fifteen-sixteenths of 1 cent per pound and a corresponding increase was made on crude magnesite to fifteen-thirty-seconds of 1 cent per pound.

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The tariff act of 1930 (par. 204) made no changes in the rates but amended the phraseology specifically to include "periclase" under the category of "dead-burned." Per short ton the present rates are as follows: Crude, $9.375; caustic, $18.75; and dead-burned, $11.50.

EXPORTS

Exports of magnesite are small. An examination of producers' and dealers' records by the United States Tariff Commission showed that during six months of 1923-24 less than 100 tons of magnesite in all forms was exported. Official statistics are not available. A few thousand tons of magnesia products, including pipe and boiler coverings (made from dolomite), are exported annually, and small quantities of magnesite brick are shipped to Canada and Mexico.

DOMESTIC CONSUMPTION AND SUPPLY

The annual additions to supply of magnesite may be considered as domestic sales plus imports, as exports are negligible. Although such figures take no account of stocks at grinding mills and in consumers' hands, they do furnish a fairly accurate index of consumption.

Magnesite supply in the United States, from 1923 to 1929 compared to the pre-war supply

(In short tons)

Year	Crude			Caustic calcined			Dead-burned		
	Domestic (sales)	Imports for consumption	Total new supply	Domestic (sales)	Imports for consumption	Total new supply	Domestic (sales)	Imports for consumption	Total new supply
Pre-war	(1)	2/15,679	15,679	1/ 5,143	2/ 6,778	11,921	--	2/28,444	128,444
1923	6,020	5,182	11,202	28,470	11,229	39,699	34,410	61,726	96,136
1924	1,570	6	1,576	26,520	16,134	42,654	29,830	48,651	78,481
1925	2,090	487	2,577	23,900	17,075	40,975	29,110	51,320	80,430
1926	1,540	608	2,148	18,580	14,758	33,338	42,540	75,535	118,075
1927	1,800	856	2,656	13,890	9,568	23,458	40,210	49,693	89,903
1928	620	762	1,382	13,310	5,474	18,784	45,230	57,007	102,237
1929	--	300	300	11,390	6,500	17,890	78,700	46,382	125,082

1/ Average production of crude magnesite, 1909-1913, as reported in published statistics, converted into caustic calcined (for use mainly in paper industry) on basis of 2.0 tons crude to 1.0 ton of caustic.

2/ Estimated from general imports (calcined and dead-burned magnesite not segregated) by countries during five-year period ending June 30, 1914.

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FOREIGN SOURCES OF SUPPLY

The foreign countries that have entered into the American magnesite situation are Austria, Czechoslovakia, Italy, Greece, British India, Canada, and to a very minor extent, Mexico and Venezuela. Small exports have been made to the United States from countries other than those named, as, for example, from Norway (via Scotland) and other European countries; and at least two British colonies, Australia and the Union of South Africa, are fairly important sources of world supply, although their output is almost exclusively for local consumption. Data with regard to these minor producing countries, however, are rather meager, and so long as it appears that the major producing localities are more than able to supply the demands of international trade, most of them can be dismissed in the present paper merely by the briefest mention.

The European producers including those in the former Austro-Hungarian Empire are associated in a cartel which fixes prices and production and allocates markets to a greater or lesser extent.

Austria

The former Austro-Hungarian Empire was the largest producer of magnesite and contained by far the largest known reserves of the mineral. Following the division of the Empire, approximately two-thirds of the productive capacity and probably a larger fraction of the reserves were allocated to the Republic of Austria. The productive deposits are found mainly in the region to the southwest of Vienna in a long and rather narrow belt extending westward from Semmering through the Murz Valley to the Tyrol. This belt, in fact, reaches across the frontiers of Italy, Jugoslavia, and Hungary, across Czechoslovakia and perhaps beyond into Germany. The workable deposits are in the form of lenses, and in Austria alone there are perhaps 10 or 12 of these lenses large enough to be worked; several are very large indeed. The largest known deposit is near the town of Veitsch, in Styria, not far from Mitterdorf and about 60 miles from Vienna. The Oberdorf and Kraubauth mines are 18 and 33 miles, respectively, farther to the southwest; and Radenthein is 50 or 75 miles still farther and more or less in the same general line. The typical Austrian magnesite is of the crystalline variety and contains enough iron to produce a good quality of dead-burned material with a minimum of fuel. Amorphous magnesite, however, is produced in the Republic and appears in exports both as raw magnesite, shipped mainly to Bavaria, and as caustic calcined magnesite which is exported to various parts of the world, Germany, however, being the principal consuming country. The United States is still the principal market for Austrian dead-burned or grain magnesite, and in 1913, before domestic supplies were developed, this country accounted for 55 per cent of the total production (mostly exported) of 200,947 metric tons of dead-burned magnesite within the Austro-Hungarian Empire. In 1929 the total shipments of raw magnesite were 1,421 metric tons, as compared with 1,932 tons in 1928. Exports of dead-burned magnesite rose from 75,597 tons in 1928 to 90,245 in 1929, 48 per cent of which went to the United States. The exports of caustic

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calcined magnesite also increased, amounting to 27,435 as compared with 23,176 tons in 1928; 68 per cent of the shipments were to Germany. Next to the United States, Germany and the United Kingdom are the principal buyers of dead-burned material, their combined purchases accounting for about one-fourth of the total exports in 1929; the remaining one-fourth was scattered among more than a dozen smaller European consuming countries and a few more distant localities.

During 1929 the total Austrian production of crude magnesite, including both crystalline and amorphous, was about 438,000 metric tons; this figure compares favorably with the output of 422,439 tons for all of Austria-Hungary in 1913 and represents a remarkable increase over the production in intervening years. Four companies contributed to this production, but two of them, the Veitscher Magnesitwerke A. G. and the Oesterreichische-Amerikanische Magnesit A. G., the latter an American-owned concern, contributed more than 92 per cent of the total. The two smaller companies, the Steirische Magnesitindustrie A. G. and the Alpenleendische Bergbaugesellschaft, m. b. H., mined only amorphous magnesite, which is not used for the manufacture of dead-burned.

At the end of August, German steel interests obtained a large share in the Veitscher Co. At present about 33 per cent of the shares of this important concern are said to be German owned (Darmstaedter und National Bank of Berlin); 25 per cent are owned by a French steel company (Creussot-Schneider); 17 per cent by an Austrian bank (Oesterreichische Creditanstalt); and the remaining 25 per cent by various other concerns and individuals.

A new company, the Alpenminen A. G., was formed by American and Austrian investors. In addition to acquiring mining rights on several magnesite deposits, most of them small, in the western part of the Federal State of Salzburg and in the eastern part of Tyrol, the new concern owns lignite mines in Carinthia.

In 1928 the industry employed 2,100 persons. Wages are fixed by collective agreement. In 1913 men were getting the equivalent of 40 to 50 cents and women were paid 20 cents per day of 10 hours. In 1928 miners received $1.14 (8 schillings) and kiln operators $1.43 (10 schillings) for 8 hours work. In 1928 there were 46 pit kilns, 3 rotary kilns, and also 11 brick ovens, but this equipment was operated at only 45 to 65 per cent capacity. In the pit (shaft) kilns, producer gas made from bituminous coal is used, but in the rotary kilns lignite may be employed in the proportion of three parts lignite to one part of coal dust. The lignite is of local origin whereas the bituminous coal comes from Upper Silesia; for a time after the war coal had to be imported from the United States. The ratio of fuel to raw magnesite in the shaft kilns is about 32 per cent. From one-third to one-half (40,000 to 50,000 tons) of the output of dead-burned magnesite is made into brick in Austrian factories. The cost of production of grain magnesite is estimated at around $12 a metric ton, to which must be added a 5 per cent commission levied by the sales cartel. The cost of crude magnesite is given as $2.50 a metric ton at the mines.

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Some portion of the Austrian magnesite is shipped by way of Hamburg, but the bulk of it has always passed through Trieste which has been an Italian port since the war. According to statements presented in connection with American tariff legislative discussion (unpublished), the freight rates as of March, 1922, were: From Radenthein to Trieste, $1.51 a metric ton; from Veitsch or Mitteldorf to Trieste, $1.29 a ton; and from Eichberg to Trieste, $1.43 a ton.

Czechoslovakia

The magnesite reserves of the Gormor district, formerly in Slovak-Hungary, were assigned to Czechoslovakia when the Empire was divided. The productive capacity of this portion of the field is only about one-half that of the Austrian. The largest operator is the Magnesite Industrie Gesellschaft with offices in Budapest, Hungary, and plants at Hunsta (Jolava); the Allgemeine Magnesite Gesellschaft with offices at Bratislava (Pressburg) and plant at Chyrne; the Vereinigte Goermoer Magnesit Gesellschaft, with offices in Budapest and plant at Hunsta (Lovinobana); and the Maehrische Magnesit Gesellschaft at Bruenn. The West Bohmische Kaolin and Schamottenwerke (formerly the Herkules A. G.) operates a factory making magnesite building materials in the Prague district, largely for export. In addition to being used locally in the iron and steel industry, Czech magnesite is shipped by rail and inland waterways to Germany and Hungary, and in some years much of the magnesite shipped to the United States from Hamburg was of Czech origin. Though somewhat less favorably situated for overseas trade, the Czechoslovakian industry is better supplied with coal than the Austrian producers.

Italy

In Italy compact magnesite has been mined at Castiglioncello, at Monterufoli, and on the island of Elba - all in the Firenze mining district, which includes the provinces of Pisa and Livorno. It has also been produced to a small extent in the province of Turin. In Elba (Livorno) the magnesite occurs in altered serpentine on the slope of the Monte Capanne, in the Commune of Campa; the production has come mostly from gopher holes and has been sold mainly for use in pottery manufacture. The Castiglioncello deposits are in the commune of Rosignano Marittimo within one mile of the Livorno-Vada railway and consist of three large veins, 3 to 10 metres thick, in serpentine near a contact with sedimentary (Eocene) rocks. The ore, which contains about 2 per cent iron oxide and 5 per cent calcium carbonate, is calcined locally and the product is made into brick at Vada. At Monterufoli (Pisa), the deposit is a vein 4 to 8 metres thick which likewise occurs in serpentine near a contact with Eocene beds, which include chalk. The raw magnesite, after removing the associated chalcedony and quartz by hand-sorting, contains under 10 per cent carbonate of lime, between 2 and 3 per cent of iron oxide, and only about 1 per cent insoluble. It is hauled in carts about 2½ kilometers to the Monterufoli station, thence by rail to Ardenza, and is finally carted to Montenero (Livorno) where it is calcined.[24]

24 The data in this paragraph are from the report of the Imperial Mineral Resources Bureau (London) on Magnesite, 1913-1919.

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Italian production rose from only a few hundred tons to over 30,000 tons annually during the war. In 1928 the output was 11,690 tons. Dead-burned magnesite is imported into Italy from Austria for local consumption and, as previously noted, much the larger part of the Austrian exports to overseas destinations, including the United States, are by way of the Italian port of Trieste.

Greece

Grecian magnesite is of the noncrystalline or amorphous type like that of California. Before the war the world's supply of magnesite marketed in the crude or caustic calcined condition came principally from deposits situated in the island of Euboea. Considerable magnesite has also been mined, principally in recent years, on the Chalcidiki Peninsula in Macedonia and on the island of Mytilene (Lesbos) off the coast of Asia Minor. Both these areas were formerly Turkish territory. Other occurrences, probably not of economic importance, have been noted in the regions of Hermioni and Atalanti and in the district north of the Gulf of Corinth.

In Euboea there are three magnesite producing districts, all located in the northern part of the island. The most important with respect both to total production and to reserves is the region of Limni-Mantoudi, but successful mines are situated near Chalkis on the Atalanti Canal to the southwest and several prospects have been opened up in the region of Mourtia some 20 miles northeast of the village of Mantoudi. In the Chalcidiki Peninsula there are likewise three districts - namely, at Yerakino, at the base of the Gulf of Cassandra; at Vavdos; and (still further to the northwest) in the vicinity of Saloniki.

According to Thoenen[25] crude magnesite can be mined in Euboea and delivered on steamers at $2.50 to $5 a ton. Miners are paid 50 to 60 drachmas (62½ to 87½ cents) per day of 8 hours. Common labor gets 40 drachmas (50 cents) and women 22 drachmas (27½ cents) a 10-hour shift. The magnesite veins are wide and mining is largely by open-cut.

The largest operator is the Anglo-Greek Magnesite Co. and there is said to be an effective combine of producers which operates successfully to maintain prices. Formerly about two-thirds of the Grecian output was shipped crude and was calcined in northern Germany or the Netherlands; most of the Grecian magnesite sold in the United States has been calcined or at least ground and packed in Rotterdam. From the official figures showing quantities of raw magnesite sold or treated in Greece it would appear that a larger proportion of the material is now calcined locally. According to the Imperial Mineral Resources Bureau,[26] large gas-fired kilns are used in Greece. Formerly these were all of the Schmatolla type but subsequently various improvements, including Morgan gas generators, Steiger kilns, and

25 Thoenen, J. R., Mining Grecian Magnesite: Eng. Min. Jour., vol. 125, No. 16, April 21, 1928, pp. 644-648.

26 Imperial Mineral Resources Bureau, Work cited in footnote 24, p. 35.

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pressure and exhaust fans have been introduced. As a result of these improvements the consumption of coal in making caustic calcined magnesite has been reduced from 6 to 7 cwts. per ton of product from the old type of bottle kiln, to 4.8 cwts. and in the latest type of kiln to only 4.6 cwts. The coal is in part imported, but lignite mined on the island of Euboea is also used for calcining magnesite.

The following table gives the official statistics of crude magnesite sold or treated by the various Grecian companies during 1928.

Crude magnesite sold or treated by Grecian companies during 1928

Company	District	Sold crude, metric tons	Treated, metric tons
Anglo-Greek Magnesite Co.	Limni	996	12,642
Do.	Chalkis	--	3,527
Do.	Pili	5,773	--
Ste. Financière de Grèce	Mantoudi	337	12,497
W. Huyzer	Chalkis	620	3,047
Do.	Limni	4,330	10,785
Ste. Internationale des Mines	Livadakia	2,774	--
C. Soulitos and P. Lamprianidis	Galatista	--	2,300
Ste. Industries Alliées de Magnésite	Xiropotamos	820	1,871
W. Huyzer (Mytilene)	Mikri Limni	--	--
E. Tragakis 1/	Polichnitos	--	--
Ste. Daphnopotamos	Mantoudi	--	7,235
Anglo Greek Magnesite Co. (Chalcidiki)	Yerakini	3,970	10,763
Ste. de Recherches et de Travaux Miniers	Vavdos	--	3,164
Miscellaneous	--	2,500	--
Total		22,120	2/ 64,304
Average value in drachmas		462.28	

1/ Produced 900 tons.
2/ Total of individual items is 67,831.

British India

The third largest producer of amorphous magnesite is British India. Most of the output has come from the "Chalk Hills" of the Salem district in Madras Presidency and the remainder has come from Mysore.

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The Chalk Hills are situated 4 or 5 miles to the north and northwest of the town of Salem, within about a mile of the Madras railway and 200 miles from the port of Madras. The magnesite occurs in interlacing veins which stand out prominently above the surrounding, serpentinized peridotite (olivine rock). According to Middlemiss,[27] magnesite constitutes from a third to a half of the total volume of the rock over an area of 620,000 square yards and about a tenth to a sixth over an area of 5,536,000 square yards. The richest outcrops form hillocks rising as much as 140 feet above the plain - indicating that an almost unlimited supply may be obtained by simple quarry methods. The magnesite is hand-sorted and sacked at the quarry, about 15 per cent of the rock broken being shipped. Calcining is done partly at the mine and partly at the port of Madras. Evidently some grinding has been done in India but the exports to the United States have consisted of lump caustic some of which has been shipped by way of the United Kingdom.

In the Mysore State magnesite deposits occur at a number of points in the Mysore and Hassan districts in the south-central part of the Indian Peninsula. Apparently the only important ones are at Dod Kanya and Dod Katur which are situated between Mysore and Nanjangud. Near the surface the material is often admixed with a nodular calcium carbonate (Kankar) but within a few feet clean magnesite containing under 0.5 per cent of lime is found.

Canada

The only important magnesite-producing area in Canada is in the Grenville district, near Calumet in Argenteuil County, Quebec - about halfway between Montreal and Ottawa. Many other occurrences are reported and there are deposits of considerable extent both of magnesite and of hydromagnesite in British Columbia but, due only in part to transportation costs, little or no commercial developments have taken place elsewhere in the Dominion.

The Quebec magnesite is mixed with dolomite and serpentine and the product is invariably high in lime. Being cheap to mine and relatively close to consuming centers in the United States, the deposits were exploited successfully during the war. As the lime content was considered an undesirable impurity by both steel makers and flooring manufacturers, production dropped off after the Armistice, reaching a post-war minimum of 3,827 metric tons in 1925. The deposits have been fully described by Wilson[28] who estimated that there were in sight in 1917, 686,900 tons of magnesite containing less than 12 per cent of lime, and 483,700 tons of magnesite-dolomite containing more than 12 per cent CaO.

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27 Quoted in Imperial Mineral Resources Bureau report: Magnesite (1913-1919), p. 17.

28 Wilson, M. E., Magnesite Deposits of Grenville District, Argenteuil County, Quebec: Memoir 93, Dept. of Mines, Canada, 1917, 87 pp.

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In recent years active work has been carried on in the laboratories of the Dominion Department of Mines at Ottawa under the direction of its National Research Council. A patent has been taken out on a process for mechanically enriching the material; it was found that light crushing of the carefully calcined rock pulverized the softer magnesite so that the portion high in lime and silica could be largely removed by screening. It was also found, after a long series of calcining experiments, that a suitable product could be made without removing the lime. It is claimed that this new dolomitic material is sufficiently refractory and that it is more quickly "burned in" in a furnace than a magnesite bottom. Both Canadian and foreign patents have been applied for on this product, which is finding a sale in Canada and in the United States and England. Methods had previously been worked out for producing a lightly calcined product suitable for use in Sorel cements. The National Research Council's staff also undertook to develop a method of making bisulphite liquor for use in the production of sulphite wood pulp. Ordinary raw magnesite used for this purpose dissolved too slowly and also produced sludge that tended to choke the towers. Calcined material likewise was unsatisfactory because of its lack of mechanical strength. The method recommended was to introduce the finely ground or slaked material with water into towers filled with coarse limestone. Research on the possibility of manufacturing refractory brick from the Canadian material is also said to have produced encouraging results. The laboratory work is being continued under a cooperative arrangement with the operating companies.[29]

In 1930 the duties on caustic calcined magnesite or plastic magnesia and those on dead-burned or sintered magnesite were increased. The present rates are 20 per cent ad valorem on imports from Great Britain and 25 per cent on imports from other countries.

Mexico

On the island of Santa Margarita in Magdalena Bay, Lower California, there are extensive deposits - estimated to contain from 300,000 to 800,000 tons of magnesite. It is a mountainous island cut up by canyons in which massive magnesite several feet thick is exposed. During and for a time after the World War, the rock, which was quite pure, was shipped coastwise to the calcining plant at Chula Vista, Calif., south of San Diego. The venture was financed by American capital.

Some deposits of magnesite have also been reported as occurring on Cape St. Lazaro in Magdalena Bay; on Cedros Island in the Bay of Sebastian Vizcaino, Lower California; and in other parts of Mexico. The entire production has been very small and all of it has apparently come from the Island of Margarita. In 1920, comparatively a good year, only 500 tons were produced.

29. Chemical News (London), The Canadian Magnesite Industry: Mar. 7, 1930, pp. 149-151.

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Venezuela

Large deposits of the massive or compact type of magnesite are found on the Island of Margarita near the northern coast of Venezuela. The chief deposits are about a mile from the Port of Porlamar and 3 miles from the Port of Pambatar, both of which have good shipping facilities. The deposits were opened up by American interests in 1912 and shipments began in the second half of 1913. Since there is no domestic market in Venezuela, the entire production has been exported in the form of crude magnesite. The maximum exports in 1916 amounted to 6,360 metric tons. In 1917, due to the necessity of conserving shipping, the importation of crude magnesite from Venezuela was virtually prohibited by the United States Shipping Board, and exports were not resumed until 1920. As a result of litigation between the lessee and the owner the mines were closed in 1921, and although a decision was rendered by the courts in favor of the lessee in 1925, no output has since been reported. The total exports have amounted to 20,060 metric tons, all of which were shipped to the United States, except for 2,000 tons shipped to Great Britain in 1920.

Before the war Venezuelan magnesite was sold at a profit for $7 per ton delivered at New York, after paying the freight of $2.25 per ton from the Port of Manzanillo. Labor is cheap and is said to be reasonably efficient. The wages of common labor were equivalent to 60 cents a day and skilled workers were getting $1 a day in 1925. The magnesite is white in color and quite free from impurities, running up to 95 per cent magnesium carbonate, 3 per cent silica, 0.55 per cent alumina and iron oxides, and 0.75 per cent lime. Four quarries were opened at the La Loma de Guerra. The yield in magnesite is said to exceed 10 per cent of the total rock broken.[30]

Other Foreign Countries

In Australia magnesite of the compact or Grecian type occurs in many different localities. The more important deposits are in and near Fifield and Piedmont in New South Wales, Heathcoate in Victoria, Tumby Bay in South Australia, and at Horseshoe near Peak Hill in Western Australia. The bulk of the Australian output, however, has come from one mine in New South Wales which produces about 10,000 tons annually, principally for the refractory needs of the Broken Hill Proprietary Co., Ltd. In 1928, New South Wales produced a total of 10,639 tons, valued at $68,331; Victoria contributed 72 tons, valued at $1,153; and South Australia produced 48 tons, valued at $437. In the Union of South Africa amorphous magnesite is found in deposits of considerable size in the Barberton district, eastern Transvaal, at various localities near the railway line between the stations of Kaapmuiden and Malelane. Kaapmuiden is about 87 miles from Delagoa Bay and 300 miles from Johannesburg. In 1913, the Transvaal produced 661 short tons of magnesite; in 1928, the output was 1,635 short tons.

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30 McDonough, Dayle C., U. S. Council Caracas. Report dated Aug. 20, 1925.

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Before the war Russia imported considerable quantities of magnesite. The domestic production amounted to 60,617 metric tons in 1913, but was insufficient to supply the requirements of the country. During recent years production has expanded substantially, reaching nearly 120,000 tons in the fiscal year of 1927-28. Imports, which amounted to 12,341 metric tons in 1913, dropped to 1 ton in the fiscal year ending Sept. 30, 1929, while exports, nonexistent in 1913, rose to 16,443 metric tons in 1928-29. Aside from the Satkin deposits in the Urals, which were worked before the war, the Khalilov deposits are now being worked. The average analysis of the Ural magnesite (calcined) is given as follows: MgO, 90-92 per cent; CaO, 3-4; SiO_2, 2-3.5; Fe_2O_3, Al_2O_3, 4-5; loss on ignition, 0.5-1 per cent.

In Germany deposits of almost theoretically pure magnesite were worked for many years near Frankenstein, Silesia. Production seems to have consisted largely of surface bowlders. In northern Spain, in the Province of Santander, about 60 kilometers by rail from seaboard, coarse crystalline magnesite occurring in lower Cretaceous limestone and dolomite strata has been mined to the extent of 1,000 tons or more annually since at least as early as 1905. The magnesite of Santander Province has been stated by some authorities to consist of breunnerite similar to that mined in Austria, but other reports indicate that it is impure hydromagnesite of rather poor quality.[31] The magnesite deposits of Norway are near Snarum in the Modum district in the southern part of the country, about 35 miles from Drammen and within easy access both to that port and to Oslo. The magnesite is found in veins averaging 13 feet thick in a mass of serpentine associated with schists and quartzite. The magnesite is remarkably pure, lime in particular being completely absent, but serpentine is added to the magnesite for sintering and brick making. The resulting product after calcining contains magnesia, 83.6 per cent; silica, 9.3 per cent; alumina, 2.0 per cent; and ferric oxide, 4.6 per cent.[32] Deposits similar to those in Norway are reported in Sweden but being rather inaccessible are not classed as commercial.

MARKETS AND PRICES

Crude magnesite is ordinarily marketed in lumps 4 to 14 inches in size because chemical manufacturers find that lump material dissolves more satisfactorily. Purity is demanded, but there are no standard specifications. Usually a white-colored material has been preferred, although frequently an iron-stained ore may be quite as good as a whiter product.

The price of crude magnesite before 1913 was approximately $8 a net ton both in California and along the Atlantic seaboard. Some contract business was done at $7 and perhaps at less, but the quotation was usually above rather than below $8. A little high-purity Grecian magnesite was sold at $20 or $25 a ton. In 1918 the wholesale price had risen only to $9.06 f.o.b. California mines and the average sales price reported by domestic producers was only $7.83; Eastern quotations, however, were two or three times

31 Imperial Mineral Resources Bureau, Magnesite (1913-1919): p. 34.
32 Imperial Mineral Resources Bureau, Page 33 of work cited.

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as high due to transportation costs. After the Armistice, import valuations declined fairly steadily, but the trend of California prices was upward, reaching a peak of $13 in 1923, after the duty under the tariff act of 1922 became operative. The declining demand for crude magnesite due to the increased substitution of caustic calcined has subsequently been reflected in lower prices. In 1929 the price of crude magnesite, f.o.b. California mines was nominally $11 a ton but there were no sales. The New York price was evidently much higher.

Caustic calcined magnesite varies considerably in chemical composition so no very definite limits can be stated. In general the magnesia content seldom if every drops below about 75 per cent and may slightly exceed 90 per cent; usually it is not less than 85 per cent. Lime (CaO) is preferably under 1.5 per cent but more often ranges from 2 to 6 per cent; silica may vary from 3 to 15 per cent; and ignition loss may be anywhere from 1 to 15 per cent. Attention is often given to the quantity of "free magnesia" rather than the total acid soluble magnesium oxide as determined by ordinary chemical analysis; magnesium carbonate and hydrate are likely to be present and being virtually inert do not contribute to the value of oxychloride cement mixtures. Caustic calcined magnesite should not be exposed for a long time to moist air before use. Color is a factor, and domestic Grade A, which is white, regularly commands $1.40 to $3 per short ton more than Grade B, which is cream colored. Grecian magnesite, calcined at Rotterdam, is slightly pink, whereas similar material, calcined at Paisley, Scotland, at a lower temperature, is white. Indian magnesite is generally considered the whitest of all and as such may command a premium. White, cream, and pink magnesite all make good stucco and flooring and the different kinds, both foreign and domestic, are often blended, with satisfactory results.[33] The difference in shade is generally so slight as to be recognizable only when different samples are examined side by side and the color of flooring or stucco depends quite as much on the color of the pebble-dash or filler as upon the magnesite. Caustic calcined magnesite is generally marketed in a ground condition; the usual size specification is 80 per cent through 200-mesh with practically all through 100-mesh.

In 1913, Grecian caustic calcined magnesite, finely ground, brought up to $35 or $40 in New York and domestic magnesite of like quality sold for $30 to $35 a ton in San Francisco. In 1918 Grade A ground magnesite was quoted at $57.50 and lump caustic at $38.80 per ton f.o.b. California mines but these prices were progressively reduced. Early in 1925 lump caustic was quoted at $35 and ground at $42.50 a ton, f.o.b. California points, but in August Grade A (80 per cent through 200-mesh) was reduced to $40 and Grade B to $38; the average sales price reported by producers in that year was $32.75 a ton. Magnesite from Greece was quoted in 1925 at $50 to $51 a ton c.i.f. New York, duty paid. The quotations for domestic material showed some improvement later, and in 1929 producers reported sales of high-grade caustic magnesite at prices as high as $45; due in part to an increase in the relative amount of high-quality material sold, the average sales value in that year was $35.94 a ton as compared with $34.23 in 1928.

33 U. S. Tariff Commission, Crude and Caustic Calcined Magnesite: Preliminary Statement to the Trade, May 19, 1926, p. 25.

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Lump caustic is shipped in burlap bags and also in bulk in box cars. The ground magnesite is packed in 150-pound sacks or paper bags or in paper-lined barrels.

Dead-burned magnesite usually contains from 8 to 14 per cent of impurities in the form of iron oxide lime and silica, as these are necessary to form the bond and to facilitate sintering. In general, material for the refractories trade must be moderately low in silica (maximum 7.5 to 8 per cent), low in lime (1.5 to 3 per cent), and exhibit no ignition loss. Shrinkage after heating up to 3,000° F. should be practically nil. A mixture of sizes ranging from approximately one-half inch down to extremely fine particles is generally preferred to either all fine or all coarse sizes.[34] Since sintered magnesite is practically uninjured by moisture, shipments are often made in bulk.

In 1913 Austrian dead-burned magnesite sold in New York at $16.25 a ton; the lowest prices recorded before the war were $15.72 f.o.b. docks at Philadelphia, $15.60 f.o.b. New York, and $15.20 f.o.b. New Orleans. In 1929 the price was $19.40 per metric ton in Austria for domestic retail business and $25.50 c.i.f. U. S. Atlantic ports. The latter price is equivalent to $23.13 per short ton, to which should be added the duty of $11.50, making the landed cost $34.63. Early in 1928 the price of domestic grain magnesite was reduced from $29 to $22 a short ton, f.o.b. Chewelah, Wash., and this was the price in 1930. The transcontinental freight rate is $18.40 per short ton, and, as the combination rail-and-water rates is only a few dollars less, the price of foreign and domestic magnesite delivered at eastern consuming centers is practically the same.

Average wholesale market prices of crude and caustic calcined magnesite, per short ton, 1913-1929 1/

Year	Prices			Year	Prices		
		Caustic[2]				Caustic[2]	
	Crude[2]	Lump	Ground		Crude[2]	Lump	Ground
1913	$ 8.00	(3)	$32.50	1922	$ 12.10	$36.50	$ 47.50
1914	9.00	(3)	37.50	1923	13.72	36.35	44.25
1915	(3)	(3)	47.50	1924	14.00	34.96	43.87
1916	9.00	(3)	47.50	1925	(3)	35.00	41.04
1917	7.45	$32.50	(3)	1926	14.00	(3)	4/41.66
1918	9.06	38.80	57.50	1927	14.00	(3)	4/40.00
1919	(3)	(3)	57.50	1928	12.00	(3)	4/41.66
1920	(3)	37.50	4/37.50	1929	11.00	(3)	4/43.00
1921	13.50	35.00	4/35.62				

1/ Data from Tariff Commission and Eng. and Min. Jour.
2/ F.o.b. California mines.
3/ Not reported.
4/ Grade "A" calcined, 80 per cent through 200 mesh.

34 Stone, R. W., Magnesite chapter in Spurr and Wormser's Marketing of Metals and Minerals, New York, 1925, p. 405.

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Average wholesale market prices of domestic dead-burned magnesite, per short ton, f.o.b. mines, 1920-1929[1]

Year	California	Washington	Year	California	Washington
1920	(2)	$33.41	1925	$30.00	$32.00
1921	(2)	35.50	1926	34.50	25.00
1922	(2)	33.00	1927	32.66	24.00
1923	(2)	33.00	1928	29.00	23.00
1924	(2)	32.50	1929	29.00	23.00

1/ Engineering and Mining Journal.
2/ Not reported.

Average sales price per short ton of crude magnesite as reported by producers, 1901-1921[1]

Year	Average value	Year	Average value	Year	Average value
1901	$ 9.11	1908	$ 3.00	1915	$ 9.00
1902	3.00	1909	4.00	1916	8.99
1903	2.83	1910	6.00	1917	9.15
1904	3.26	1911	8.00	1918	7.83
1905	3.87	1912	8.00	1919	7.99
1906	3.00	1913	8.00	1920	9.05
1907	3.00	1914	11.00	1921	10.65

1/ Data from the Mineral Resources of the United States (Annual), U. S. Geological Survey and U. S. Bureau of Mines.

Average sales price per short ton of crude, calcined, and dead-burned magnesite as reported by producers, 1922-1929[1]

Year	Crude	Caustic calcined	Dead-burned
1922	$10.25	$37.00	$23.30
1923	13.00	36.38	19.50
1924	13.00	33.30	26.40
1925	12.58	32.75	31.74
1926	11.32	32.10	25.62
1927	9.52	32.60	24.63
1928	9.18	34.17	23.80
1929	(2)	35.56	19.60

1/ Mineral Resources of the United States (Annual). U. S. Geological Survey and U. S. Bureau of Mines.
2/ None sold.

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